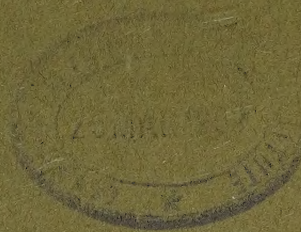
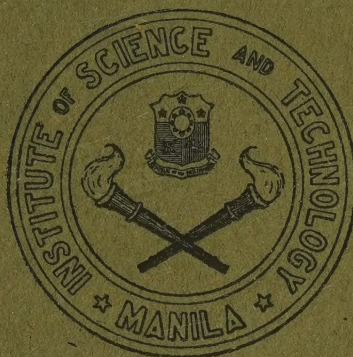


VOL. 80, No. 1

MARCH, 1951

THE PHILIPPINE JOURNAL OF SCIENCE



MANILA
BUREAU OF PRINTING
1951

20049

THE PHILIPPINE JOURNAL OF SCIENCE

Published by the Institute of Science and Technology
(Formerly Bureau of Science)

A. S. ARGUELLES, D.Sc., *Editor*

EDUARDO QUISUMBING, Ph.D., *Associate Editor*

CONTRIBUTING EDITORS

Chemistry

MANUEL L. ROXAS, Ph.D.; F. T. ADRIANO, Ph.D.

JOAQUIN MARAÑON, D.Sc.; R. H. AGUILAR, Ch.E.

PATROCINIO VALENZUELA, Ph.D.; MARCOS M. ALICANTE, Ph.D.

A. J. HERMANO, D.Sc.; FELIX V. ESPINO, Ch.E.

Geology

V. ELICAÑO, B.S.; ANTONIO D. ALVIR, Ph.D.; JOSE FELICIANO, Ph.D.

Experimental Medicine

DANIEL DE LA PAZ, M.D.; ARTURO GARCIA, M.D.; ONOFRE GARCIA, M.D.

CRISTOBAL MANALANG, M.D.; ISABELO CONCEPCION, M.D.

H. W. WADE, M.D.; WALFRIDO DE LEON, M.D.

Clinical Medicine

ANTONIO SISON, M.D.; LIBORIO GOMEZ, M.D., Ph.D.; H. LARA, M.D.

JOSE RODRIGUEZ, M.D.; CARMELO REYES, M.D.

Botany

ELMER D. MERRILL, D.Sc.; E. B. COPELAND, Ph.D.; A. F. FISCHER, C.E., M.F.

T. G. FAJARDO, Ph.D.; NICANOR G. TEODORO, Ph.D.

FELICIANO M. CLARA, Ph.D.; NEMESIO B. MENDIOLA, Ph.D.

Zoölogy

LEOPOLDO B. UICHANCO, D.Sc.; DEOGRACIAS V. VILLADOLID, Ph.D.

HERACLIO R. MONTALBAN, M.A.; GONZALO MERINO, Ph.D.

CANUTO G. MANUEL, D.Sc.; MANUEL D. SUMULONG, M.S., D.V.M.

LOPE M. YUTUC, D.V.M.; FAUSTINO Q. OTANES, M.S.

LEOPOLDO S. CLEMENTE, Ph.D.

Anthropology

H. O. BEYER, M.A.; RICARDO E. GALANG, M.A.

THE PHILIPPINE JOURNAL OF SCIENCE

VOL. 80

MARCH, 1951

No. 1

THE NATURE OF PHILIPPINE PORCELAIN PART I: IMPORTANT RAW MATERIALS .

BY GIL O. OPIANA

Of the Institute of Science and Technology, Manila

It is indeed strange that in the Philippines up to this time, the porcelain industry is not progressing very much unlike in the neighboring countries—India, China and Japan. This is probably due to the following factors: (1) cheapness of the products, (2) lack of local inducement and patronage, (3) inadequate knowledge of raw materials, (4) because of certain ideology, that it is cheaper and better to buy than to make, (5) the nature of work of the country's population—engaged in agricultural pursuits, and (6) the bounty of nature for an easy living with little effort.

The present economic situation caused by the last war, however, has changed the picture and because of import control measures, the country has to engage in local manufacture and promote native industries to stave off financial crisis. Ways and means are being studied to look into the possibilities of local raw materials for the manufacture of some imported products. The use of native clays, rocks, minerals, etc., for porcelain manufacture and other ceramic products that are heavily imported (P30,000,000 a year) comes to the front.

Early attempts.—During the early part of the American regime, an attempt was made by Mr. Zobel to make porcelain. A Japanese artisan was employed. The trials did not succeed for unknown reasons although some products were exhibited known before the war as "Zobel Collection." Unluckily all were burned.

The Philippine School of Arts and Trades gave some ceramic courses too. Kilns were built for trial firings. In Sta. Cruz, Laguna, a kiln was constructed by the high school principal. Both these attempts did not prosper. With the help of Chinese potters, a vitrified ceramic product called "Tapayan" is being made by the natives from rice paddy clay mixed with fine river sand. They also manufacture flower pots from red brick clays that are glazed with low fusing lead glazes.

Chemists of the then Bureau of Science and other workers studied the native methods of pottery making in the Islands and made some tests on samples of white and red clays including their chemical analyses. These studies led to the establishment of brick plants in some regions. A modern plant—Ceramic Industry of the Philippines—manufacturing bricks (solid and hollow) and tiles of various shapes and sizes was also organized. Further work showed the possibilities of some raw materials for other ceramic products.

Object.—This paper is the first of a series dealing on the nature of Philippine porcelain.

Brief history of porcelain.—Porcelain is the term used to that ceramic product that is infusible, hard, translucent and of white body. Its hardness is classified as No. 6 or No. 6.5 in the Moh scale and has a bell sound when struck. Being a ceramic product, it is obtained by mixing various earth materials such as clays, rocks (feldspars), silica, etc., powdered, molded and fired at high temperature.

The history of porcelain goes back to ancient times, but it could be admitted that it is of Chinese origin and of the sixteenth century product. From China, it went to Japan via Korea, to the South and finally to Europe about the beginning of the seventeenth century. In Europe, technical studies were made. Among the early workers were Dwight of England, Böttger of Germany and Brogniart of France. Unlike in England, the development of porcelain was always under the patronage of certain princes and kings. This was particularly true in China, Japan, Germany and France.

As to the various porcelain products produced in the different countries, there were differences. The hard porcelains were of German type and the soft ones were those of China, Japan and France. England did not adopt either the German or the French type. Bone china, a type of porcelain produced by mixing a certain type of clay and bone ash, was developed. The advantage of low temperature porcelain fired between

1250°C and 1300°C, which was the one made in China and Japan, was recognized by the variety of colors that were used to decorate the products. European manufacturers followed this type, hence, the extensive researches in Sevres (France), Meissen (Germany) and Seto (Japan). It could be said in passing that the different eras in Europe, China and Japan could be traced through the kind of porcelain made. The early center of porcelain manufacture in China was King-te-chen where the priest D'Entrecolles got the information he sent to Europe.

The composition of porcelain is variable as reported in different publications. The reason for this lies in the degree of kaolinization and the amount of impurities present. The range of the mixture is given below:

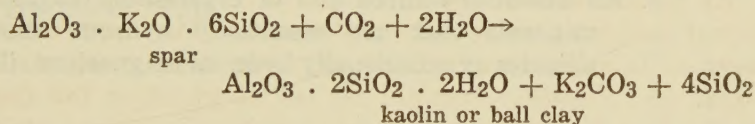
	Per cent
Kaolin	35-65
Feldspar	20-40
Quartz	15-25

Porcelain, being an article of commerce of high order, needs strict requirement in manufacture. A knowledge of the raw materials is important for the success of the enterprise.

RAW MATERIALS

Clays.—The clays used in porcelain making are those containing very little amount of iron and other impurities. Proper selection and washing are the most common methods of eliminating many of them. Iron is removed by magnetic separation.

Two kinds of clays are used viz: ball clay which is highly plastic and kaolin that has very little plasticity. These clays are the result of what is termed "kaolinization" or the weathering and disintegration of the igneous rocks (the spars, granite, etc.) when acted upon by the forces of nature. Carbon dioxide and water enter into the reaction as given below using potash spar:



In rocks, the spars (potash, soda and lime) are associated with other substances such as MgO , Fe_2O_3 , CaO , TiO_2 , P_2O_5 , SO_3 and others. The resulting kaolin and/or ball clay have plenty of impurities and consequently different treatments are needed for purification. Washing, sedimentation, filtration and drying are employed. As shown above, kaolin and/or ball clays are formed during kaolinization. These end products, although somewhat similar in composition, differ widely in physical properties particularly in plasticity, bonding strength and fusing points.

The ball clays are very plastic and of high bonding power but somewhat slightly lower in fusing point than the kaolin (1650°C). The addition of ball clay to the porcelain body is to give strength to the raw products so as to avoid breakage. Plasticity imparts that property of moldability without being distorted even in thin sheets.

As to the nature of plasticity of clays, there are many theories advanced. Among these are the following:

1. Plate theory.
2. Colloidal theory.
3. Mechanical theory – molecular attraction.
4. Organic theory.

To these may be added the new concept of clay molecule-crystal-structure. None of these could very well explain the phenomenon of plasticity. It is expected that more X-ray studies would reveal the mechanics of plasticity.

The kaolins possess very little plasticity. The amount of clay (ball clay and kaolin) in porcelain body varies from 25 per cent to 65 per cent.

X-ray examination of clay particles reveals that the clay minerals are crystalline and according to this finding, "clay as used today carries with it three implications":

1. A natural material with plastic properties.
2. An essential composition of particles of very fine size grades.
3. An essential composition of crystalline fragments of minerals that are essentially hydrous aluminum silicates or occasionally hydrous magnesium silicates.

Because the process of weathering the igneous rocks is not a uniform reaction and under different conditions, we should expect various degrees of degradation products. The factors that may determine the properties of clays due to uneven conditions, among other things, are given below:

1. Clay mineral composition—the relative abundance of clay mineral components and particle-size distribution.
2. Non-clay mineral composition—their relative abundance.
3. Electrolyte content—exchangeable bases and any water soluble salts.
4. Organic content.
5. Miscellaneous textural characteristics.

We should find, therefore, plenty of variables (chemical and physical) in the study of clays. Articles are very voluminous on the subject especially those affecting the porcelain bodies by the different substances found in clay minerals. There are also those related to ageing and the addition of water to the clay molecule on which there are many conflicting views. By the further use of X-ray in clay mineral studies, these differences could be settled down and a more scientific explanation could be given. Recently, an international committee called CIPEA was formed in Europe devoted to the study of clay.

Composition of Philippine porcelain clays.—In porcelain work, the chemical composition of clays is somewhat variable depending upon the mother rock from which they originated by the process of kaolinization already described.

Table 1 shows the analyses of local and foreign kaolins. A critical examination of these figures reveals the existence of more soda than potash in Philippine kaolins. Also, alumina is rather low compared to that of other countries. The reason for these discrepancies will be shown in the latter part of this paper. The physical properties of these clays including the spars are under study.

TABLE 1.—Analyses of porcelain clays.

Type	No.	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Ignition loss	Source
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
Foreign	1	54.00	40.7	0.30	0.70	0.10	0.30	0.30	12.4	India
	2	43.25	37.64	0.46	---	0.40	0.30	0.25	12.02	England
	3	48.55	33.34	2.44	0.35	0.40	0.61	0.10	16.45	U.S.
	4	48.04	37.84	0.83	0.50	0.39	0.55	0.23	14.33	Japan
	5	44.46	37.02	0.27	0.63	0.25	0.82	0.36	12.34	Korea
Local	6	44.46	38.07	0.87	0.12	0.36	0.53	1.30	14.42	Hongkong
	1	45.65	28.93	1.77	1.12	0.36	0.52	0.43	25.66	Pansol
	2	43.90	27.54	0.91	1.12	---	1.42	2.83	22.14	Pakolago
	3	61.50	27.76	2.76	0.46	0.37	1.41	1.41	8.20	Iloilo
	4	70.42	19.16	1.47	0.11	0.77	1.37	1.57	6.17	Capiz
	5	75.19	13.56	1.47	1.73	0.63	0.83	2.79	3.25	Angat

TABLE 2.—Analyses of spars.

Type	No.	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Ignition loss	Source
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
Foreign	1	66.40	18.10	0.09	0.40	---	10.70	3.30	0.50	S. Dakota
	2	72.50	15.60	0.11	0.40	---	7.50	3.20	0.80	N. Carolina
	3	69.30	18.60	0.07	0.90	---	2.40	8.90	0.10	U.S. Soda spar
	4	69.56	17.06	0.44	---	---	6.76	4.66	0.62	Japan
	5	64.17	20.03	0.15	0.44	0.59	10.72	3.70	0.40	Japan Soda spar
Local	6	78.82	13.05	0.11	0.28	---	0.25	6.43	1.02	Japan Soda spar
	1	68.86	18.16	0.24	1.01	0.39	0.42	7.97	0.30	Baruen
	2	62.16	13.24	3.20	4.15	2.01	4.22	2.90	5.01	Tiwi
	3	54.90	21.54	1.96	6.81	2.02	2.84	7.08	4.20	Bulacan adobe
	4	66.55	22.34	1.87	4.74	2.36	2.84	2.36	4.86	Magalang adobe
	5	60.20	16.84	3.36	3.93	2.03	1.94	2.43	8.80	

Philippine spars.—Another component of porcelain is the spar (K-spar or Na-spar or Ca-spar). There are many feldspathic materials in the Philippines.

Table 2 gives the analyses of foreign and local spars. On the average, there is more soda than potash in the native spars.

According to geological reports, the Philippines is underlain by basic rocks. Temperate countries have acidic or granitic rocks. Potash spar is predominant in their clay deposits. Soda and lime spars are found mostly in basic rocks like those of the Philippines. Whatever the reasons, no body dared to explain except by saying that it is their natural composition. Unconfirmed information regarding the presence of granitic rocks in some parts of the Philippines, especially in Mindoro, was given to the author. It does not necessarily follow, however, that just because soda spars are predominant in the Islands, we may not have potash spar. There are also soda spars in temperate regions and we may find some potash deposits here also.

In a paper read by the author before the war in a seminar of the then Bureau of Science, "On the presence of soda spar in the Philippines," it was predicted that there exist in the Philippines soda spars. This prediction was based on a critical examination of the different analyses of rocks, soils and similar materials, which were published. The predominance of soda over potash in the results was noted. As a test, search was made in some parts of the Philippines. The Baruen soda spar was located in Ilocos Norte. A sample rich in soda was also submitted from Albay. The findings led to the conclusion that adobe, a very common rock found in many provinces, is a source of spar. The material contains plenty of iron that is quite detrimental to porcelain bodies. Also, the amount of lime and magnesia is somewhat high.

Silica.—The source of silica in porcelain manufacture is usually silica rocks and siliceous clays.

In Table 3 are given the analyses of siliceous materials—foreign and local. From the figures, it can be safely said that there are many sources of silica in the Islands for porcelain and other ceramic work.

Lime and magnesia.—Lime (limestone) is used more in porcelain than magnesia especially in soft porcelain glazes. Magnesia is used in glazes for electrical insulators. Lately, however, talc became an important constituent of what is called steatite bodies for tablewares and insulators. Table 4 shows the analy-

TABLE 3.—Analyses of siliceous materials.

No.	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Loss	Source
								Ignition	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	
Foreign	1	98.00	1.05	0.20	0.10	---	---	---	Japan
	2	98.67	0.86	0.02	0.31	---	---	---	Japan
	3	80.37	13.92	0.39	0.03	2.72	0.56	2.40	Japan
	4	77.98	14.62	0.37	0.23	2.11	0.67	3.00	Japan
	5	80.35	9.94	0.22	2.55	2.97	0.10	3.81	Japan
	1	86.60	8.12	0.43	1.20	2.58	---	---	Lubang
	2	95.49	0.94	---	0.86	1.08	---	---	Rice-hull
	3	94.06	0.31	2.09	0.22	0.19	0.48	0.48	Baguio
	4	75.19	13.56	1.47	1.73	0.83	2.79	3.25	Angat
	5	70.42	19.16	2.76	0.11	0.77	1.07	5.17	Capiz
Local	6	75-85	4-8	2-3	15-17	4-7	0.57	0.1	Bagasse Ash

TABLE 4.—Analyses of limestone and dolomite.

No.	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	Loss Ignition	Source
Foreign	61.88	1.08	0.04	0.38	31.93	---	---	4.53	Korea
	4.66	0.82	0.08	33.03	17.64	---	---	43.85	Japan
	0.40	0.20	0.02	55.05	0.04	0.20	---	43.80	Japan
	52.00	3.66	3.84	11.40	23.61	0.52	---	4.10	Zambales
Local	0.86	---	0.23	0.46	---	---	---	43.45	Cebu
	1.12	---	0.15	54.69	1.19	0.77	---	43.41	Binangonan
	75-85	4-8	2-3	53.78	15-17	4-7	---	0.10	Bagasse
	---	---	---	2-3	---	---	---	---	---

ses of these materials. Local magnesia contains plenty of iron which is undesirable. In the case of limestone, there is practically no difference between the foreign and local materials.

SUMMARY

Philippine porcelain in general has soda spar bodies and lime soda spar glazes. This is somewhat different from that of other countries like the United States, Europe, China and Japan which use potash spar.

Silica, spar, limestone and different kinds of clays that are needed in the manufacture of porcelain are available. Deposits of these materials are scattered throughout the Islands. Iron is a common impurity of these materials.

The Ceramic Section of the Institute of Science and Technology is making extensive tests of local ceramic materials for their possibilities in porcelain manufacture and other ceramic products.

REFERENCES

- ADAMS, G. T. and W. E. PRATT. Philippine pottery. *Philip. Jour. Sci.* 5A (1910) 143.
- CHRISTIE, E. B. Notes on pottery industry in San Nicolas, Ilocos Norte. *Philip. Jour. Sci.* 9D (1916) 117.
- COX, A. J. The occurrence, composition and radio activity of the clays from Luzon, *Ibid.* 2A (1907) 413.
- DAR JUAN, T. and F. D. REYES. Clay products. *The Mineral Resources of the Philippine Islands (1921-1925)* 91-98.
- DILLON, E. *Porcelain*. London, Methuen & Co., 1904.
- FERGUSON, H. G. Notes on the occurrence of ryolite in Cebu. *Philip. Jour. Sci.* 2A (1907) 407.
- GRIM, R. E. Modern concepts of clay materials. *Jour. Geology* 50 (1942) 225.
- OPIANA, G. O. Clay-asbestos shingles. *Philip. Jour. Sci.* 75 (1941) 159.
- OPIANA, G. O. Glazing Philippine pottery ware. *Philip. Jour. Sci.* 76 (1944) 29.
- OPIANA, G. O. and F. P. Santos. *Ceramics—Its role in the industrial development and its possibilities in the Philippines*. *Chem. Eng. Jour. (Phil.)* (2) 1 (1949) 25.
- OPIANA, G. O. and F. M. VILLANUEVA. *Ceramic industries of Japan*. December, 1948. Unpublished.
- OPIANA, G. O. and H. MORENO. Some Philippine ceramic materials. *Philip. Jour. Sci.* 74 (1941) 385.
- RIES, H. *Clays—Their occurrence, properties and uses*. Third edition. New York, John Wiley and sons, Inc., 1927. 613p.

- TOLENTINO, P. T. and A. CLEMENTE. Composition and absorptive power of some Philippine clays. *Nat. and Appl. Sci. Bull.* **5** (1936) 159.
- WILSON, H. *Ceramics: Clay technology*. First edition. New York, McGraw-Hill Book Co., Inc., 1927. 296 p.
- WITT, J. C. Philippine paving brick materials: A preliminary report. *Philip. Jour. Sci.* **11A** (1916) 203.
- WITT, J. C. Methods of burning pottery in the vicinity of Manila and their influence in the quality of products. *Philip. Jour. Sci.* **13A** (1918) 59.

PHILIPPINE ACANTHACEÆ, I

By C. E. B. BREMEKAMP

Botanisch Museum en Herbarium, Utrecht

Some months ago I received from Dr. E. D. Merrill a batch of Philippine *Acanthaceae* that had been collected in the last three years by the Philippine National Herbarium. It proved to contain inter alia seven new species of which descriptions are given below. Of the species that were already known from this area, three had to be transferred to genera that had not yet been recognized at the time these species were discovered. They are:

1. *HYMENOCHLAENA PALAWANENSIS* (Elm.) Brem. comb. nov.

Strobilanthes palawanensis Elm., Leaf. Philip. Bot. 5 (1913) 1686.

Goldfussia palawanensis (Elm.) Brem., in Verh. Ned. Akad. v.

Wetensch., Afd. Natuurk., Sect. 2, 14¹ (1944) 232.

At the time I transferred this species to *Goldfussia*, I knew it from the description only which makes no mention of the seeds. The structure of the seedcoat with its large areola extending nearly to the margin, where it is met by a narrow zone consisting of thin-walled cells that go out into annulate hairs, and the peculiar decurrent bracts prove that it can not be included in *Goldfussia*, but that it is a *Hymenochlaena*. It differs from the two other representatives of this genus by the fertility of the two shorter stamens, and my generic description (op. cit. 301), which says "Stamina interiora ad staminodia redacta," therefore will have to be changed; in future it should be read "Stamina interiora breviora, nunc fertilia, nunc ad staminodia redacta." For the names of the other Philippine *Strobilanthinae* I refer to the work quoted above.

2. *CALOPHANOIDES PULGARENSIS* (Elm.) Brem. comb. nov.

Hypoestes pulgarensis Elm., Leaf. Philip. Bot. 5 (1913) 1698.

Polytrema pulgarensis (Elmer) Merr., Philip. Jour. Sci. 10C (1915) 341.

Hallieracantha elmeri Merr., Philip. Jour. Sci. 20 (1922) 457.

Some further particulars on this species and on some other ones that are to be referred to *Calophanoides*, are given in a note attached to the description of *C. pubescens* Brem. n. sp. v. infra.

3. **RHYTICALYMMMA VIDALII** (C. B. Clarke ex Merr.) Brem. comb. nov.

Justicia vidalii C. B. Clarke ex Merr., in Philip. Jour. Sci. Suppl. 1 (1906) 248.

The genus *Rhyticalymma* was created by me in Verh. Kon. Ned. Akad. v. Wetensch., Afd. Natuurk., Sect. 2, 45 (1948) 60, for a number of species formerly included in *Justicia*. *R. vidalii*, which seems to be confined to Palawan, comes very near to *R. vittatum* (Hall. f.) Brem. l. c. *Justicia vittata* Hall. f. in Nov. Act. Nat. Cur. 70 (1897) 211, t. 13, a species known from Sumatra and Borneo. The main difference between these two species lies in the cilia along the margin of the bracts. In *R. vittatum* they form a long and dense fringe, but in *R. vidalii* their number is but small and they do not form a conspicuous fringe.

For the species recorded in Merrill's "Enumeration" under the names *Pseuderanthemum pulchellum* (Hort.) Merr. and *Peristrophe bivalvis* (L.) Merr., I have re-introduced the names *Pseuderanthemum bicolor* (Schrank) Radlk. and *Peristrophe tinctoria* (Roxb.) Nees, and *Dipteracanthus lanceolatus* Nees, which was sunk by Merrill in *D. repens* (L.) Hassk. or *Ruellia repens* L., as the latter is called in the "Enumeration," was restored by me. It differs from *D. repens*, which is also found in the Philippines, in the pubescent capsule, the 2 to 4 instead of 5 or 6 ovules per ovary cell, and the tuberculate instead of alveolate pollen grains. With regard to the names of the other *Ruellia* occurring in the Philippines I refer to a paper on this group by Bremekamp and Nannenga-Bremekamp in Verh. Kon. Ned. Akad. v. Wetensch., Afd. Natuurk. Sect. 2, 45¹ (1948) 3.

The reasons for the re-instatement of the name *Peristrophe tinctoria* were given by me in Verh. Kon. Ned. Akad. v. Wetensch., Afd. Natuurk., Sect. 2, 45² (1948) 29, *Pseuderanthemum pulchellum* had to be rejected because the name *Eranthemum pulchellum* Hort. (1810) on which it is based, is a later homonym of *Eranthemum pulchellum* Andrews, Bot. Rep. (1800) 2, t. 88. The latter has blue flowers subtended by large foliaceous bracts, and is therefore a true *Eranthemum*.

The collection further contained three recently introduced American species, which have a fair chance to establish them-

selves in the Philippines. All three were collected at Los Baños in Laguna Province, Luzon. The first is *Pachystachys coccinea* (Aubl.) Nees, a robust herb with a dense spike of large red flowers. It is often grown as a garden plant in tropical countries, but it does not seem to produce ripe seeds. Its chance to spread rests on the faculty of the detached stems to strike root. The second is *Drejera boliviensis* Nees, a high climber with a woody stem and long-tubed red flowers. These two are natives of Tropical South America. The third one is a Mexican plant. It was described by F. S. Brandegees in Univ. Cal. Publ. 4 (1912) 278, under the name *Beloperone guttata*, but it differs from the true representatives of *Beloperone* in the large size of the bracts, in the white flowers, in the structure of the pollen grains with their three pores bounded on each side by a single row of rather large flat shields, and in the flattened seeds. In *Beloperone* the bracts are always small, the corolla red, the pollen grains provided with two pores that are bounded on each side by a threefold row of granules, and the seeds are always distinctly swollen. On account of these rather important differences the plant described by Brandegees was transferred by me in Verh. Kon. Ned. Akad. v. Wetensch., Afd. Natuurk., Sect. 2, 45² (1948) 54, to a new genus *Calliaspidia*. Further study, however, has shown that the latter is identical with the genus *Drejerella* proposed by Lindau in Urban, Symb. Antill. 2 (1900) 222. Lindau's description contains but few details, and does not give a good idea of the genus, because it ascribes to its species "Spangpollen," i.e. pollen grains with pores situated in grooves that are bounded on each side by a solid stave of a similar character as the wider intervening parts from which the staves are separated by narrow fissures; and this is incorrect, for in reality the pores are bounded on each side by a row of rather flat shields that lack the relief shown by the area outside these rows. The genus, moreover, is said to be a near ally of *Drejera* Nees, whereas in reality it belongs in the neighborhood of *Beloperone*. It differs from *Drejera* in the presence of a rugula and a palate, in the insertion of the thecae at unequal height, and in the presence of a spur at the base of at least one of the latter. Even in the structure of the pollen grains, on which Lindau mainly based his opinion, there is but little resemblance, for, as stated above, the pores are not bounded by solid staves but by rows of shields, and they are not subglobose but doleiform. If in my description of

Calliaspidia the word "lateritiae" in the description of the bracts is erased, and if we read instead of "thecis ambobus brevissime calcaratis" "theca inferiore vel thecis ambobus calcaratis," it will form a useful substitute for Lindau's far too incomplete description of *Drejerella*. *Beloperone guttata* F. S. Brandegee will have to be quoted in future as *Drejerella guttata* (F. S. Brandegee) Brem. comb. nov.

Of the seven new species five belong to *Hemigraphis*, a genus that is particularly well represented in the Philippines, one to *Hypoestes*, and one to *Calophanoides*.

HEMIGRAPHIS DIFFUSA Brem. sp. nov.

Series *Pubicrurium*, structura pollinis speciebus orientalibus congruens et inter eas ad *H. mediocrem* Brem. accedens sed foliis longius petiolatis, supra dense pilosis, bracteis angustioribus, thecis basi obtusis, granulis pollinis numero majore virgarum instructis ab ea faciliter distinguenda, habitu *H. culionensi* Brem. similior a qua tamen granulis pollinis virgas 27 punctatas exhibentibus recedit et insuper foliis basi cuneatis vel subrotundatis, nervis utroque latere costae plerumque 5, thecis basi obtusis differt.

Herba diffusa stolonibus vagans, caulibus floriferis ascendentibus. Caules ramique primum dense, deinde sparsius hirsuti, circ. 1 mm diam. Folia petiolo hirsuto 0.2–2.0 cm longo munita; lamina oblanceolata, oblonga vel elliptica, 2.2–4.0 cm longa, 1.2–2.0 cm lata, apice obtusa vel rotundata, basi cuneata vel subrotundata, margine plus minusve crenata, subcoriacea, supra primum densissime, deinde dense hirsuta, subtus costa nervisque et interdum inter nervos sparse hirsuta, cystolithis plerumque difficiliter distinguendis, infra interdum nigrescentibus, nervis utroque latere costae plerumque 5. Spicae solitariae vel binae. Pedunculus hirtellus, 0.5–4 cm longus. Rachis usque ad 1 cm longa. Bractea 3- vel 4-parae, late lanceolatae 7–10 mm longae et usque ad 3.5 mm latae, margine et costa ciliatae. Calyx 7 mm altus; lobi margine et costa ciliati. Corolla alba, 12 mm longa, extus glabra. Stamina antheris apice obtusis, thecis basi obtusis. Granula pollinis virgis 27 punctatis ornata, magnitudine valde inaequalia, 42–52 μ longa et 33–42 μ diam. Ovarium apice hirtellum, utroque loculo ovulis 4 instructo. Stylus vix conspicue hirtellus. Capsula nondum visa.

PALAWAN, Puerto Princesa, Bacuñgan, at sea level, *Philip. Nat. Herb.* 272 G. E. Edaño (type), "along a rise in the forest"; ibidem, id. *Phil. Nat. Herb.* 261.

In the last-named specimen the leaves are somewhat wider than in the type and distinctly rounded at both ends, their petiole is somewhat shorter (0.2 to 0.8 cm against 0.5 to 2.0 cm in the type), and the spikes are provided with a shorter peduncle. The underside of the leaves is purple.

The 27 bands of the pollen grains are a rather strange feature, for in the other species of the series *Pubicrures* the number is either 18 or 21, but the hairyness of the filaments of the longer stamens and the strong resemblance to *H. culionensis* Brem. and *H. mediocris* Brem. leave no doubt with regard to its position.

HEMIGRAPHIS PALAWANENSIS Brem. sp. nov.

Series *Pubicrurium*, maxime ut *H. cumingiana* (Nees) F.-Vill. sed statura parva, foliis margine subintegra munitis, spicis paucifloris, bracteis minoribus ab ea recedens.

Herba suberecta, simplex vel parce ramosa, 20–30 cm alta. Caulis ramique primum pilis basiscopis pubescentes, deinde glabrescentes. Folia petiolo gracili, pilis basiscopis sparse pubescente, 1–1.5 cm longo instructa; lamina ovato-lanceolata vel lanceolata, plerumque 5–7.5 cm longa et 2–2.5 cm. lata, apice acuta vel acuminata, cacumine extremo tamen haud raro obtuso, basi acuta vel contracta, margine subintegra et vix conspicue recurvata, tenuis, discolor, supra primum setulis sparsis scabrida, deinde sublaevis, subtus densius scabridula, cystolithis supra conspicuis, subtus vix distinguendis, nervis utroque latere costae plerumque 4. Spicae terminales et insuper in axillis foliorum supremorum, magnitudine valde redactorum solitariae, pauciflorae. Pedunculi 1–6 cm longi, pilis basiscopis dense vestiti. Rachis pilis basiscopis brevioribus vestita. Bractee infimae lanceolatae, 7–12 mm longae et 3–4 mm latae; bractee aliae ovatae, 8 mm longae et 5–7 mm latae, margine et costa breviter ciliatae, subtus extra costam parce et breviter pubescentes. Calyx 7 mm longus. Corolla alba, 14 mm longa, extus dimidio superiore puberula. Stamina antheris complanatis, apice obtusis, thecis basi acutis. Granula pollinis virgis 18 conspicue carunculatis ornata, 45–60 μ longa et 32–40 μ diam. Ovarium dimidio superiore pubescens, utroque loculo ovulis 4. Stylus hirtellus. Capsula nondum visa.

PALAWAN, Puerto Princesa, Babuyan, at sea level, *Philip. Nat. Herb.* 167 G. E. Edaña (type), "on forested slope."

Var. HIRSUTA Brem. var. nov.

Caule petiolisque primum dense hirsutis, lamina supra et facie inferiore costae pilis longioribus sed haud rigidis sparsa, margine

solum scabrida, bracteis margine et costa longe ciliatis a typo recedens.

PALAWAN, Puerto Princesa, Babuyan, at sea level, *Philip. Nat. Herb.* 298 G. E. Edaña (type of the var.).

This species and the two following ones belong to the same circle of affinity as *H. cumingiana* (Nees) F.- Vill., *H. benguetensis* Brem., *H. oblongibractea* Brem., *H. pachyphylla* Merr. and *H. samarensis* Brem. The group is also represented in Celebes. Further study of the Philippine flora will doubtless lead to the distinction of an even larger number of species in this group, for the material which so far has been brought together under the name *H. cumingiana* is far from uniform.

HEMIGRAPHIS LANCIBRACTEA Brem. sp. nov.

Series *Pubicrurium*, maxime ut *H. cumingiana* (Nees) F.- Vill. et *H. oblongibractea* Brem. sed bracteis angustioribus a *H. cumingiana*, foliis laterioribus, bracteis brevioribus et angustioribus, apice basique subacutis a *H. oblongibractea* recedens.

Herba suberecta, parce ramosa. Caulis ramique primum pilis brevibus basiscopis sparse pubescentes, mox glabrescentes. Folia petiolo 1.5–3 cm longo, subtus pilis basiscopis puberulo-pubescenti instructa; lamina ovata 6–14 cm longa et 2.5–7 cm lata, rarius (*Philip. Nat. Herb.* 3473 Edaña) lanceolata, casu quo 3–7 cm longa et 0.6–2.7 cm lata, utroque extremo attenuata, apice ipso tamen obtusa, margine sinuosa, non distincte recurvata, tenuior, paulum discolor, supra glaberrima sed vix nitidula, subtus costa nervisque pilis basiscopis sparse et vix conspicue pubescens, cystolithis supra ubique, subtus praesertim costa nervisque conspicuis, nervis utroque latere costis 5–6 vel in foliis lanceolatis 2–3. Spicae terminales et axillares, plus minusve paniculatae, ramulis paniculia foliis multo redactis suffultis. Pedunculus 0.5–2 cm longus, pilis basiscopis brevibus parce et vix conspicue pubescens. Bractee anguste ovato-lanceolatae, 7–10 mm longae et 2.5–3 mm latae, apice subacutae, basi acutae, margine longe et conspicue albo-ciliatae, subtus costa nervisque breviter pubescentes, inter nervos interdum puberulae. Calyx bractee primum subaequilongus, post anthesin eam distincte excedens; lobi margine et costa pilis brevibus ciliolati. Corolla alba, 14 mm longa, extus primum apicem versus puberulo-pubescentis. Stamina antheris complanatis, apice obtusis, thecis basi acutis. Granula pollinis virgis 18 subcarunculatis ornata, 40 μ longa et 29 μ diam. Ovarium dimidio superiore pubescens, utroque loculo ovulis 4. Stylus hirtellus. Capsula dimidio superiore puberulo-pubescentis, 8-seminalis.

MINDORO, Mt. Halcon, Cateriran River, alt. 850 m, *Phil. Nat. Herb.* 3329 G. E. Edaña (type), "on forested slope"; ibidem, Dulangan River, alt. 150 m. id. *Philip. Nat. Herb.* 3393 et 3473.

The last-named specimen has lanceolate leaves, but agrees in other respects very well with the type. It might represent a distinct variety.

This species comes doubtless very near to *H. oblongibractea* Brem., but the shape of the bracts is quite different.

HEMIGRAPHIS POLILLENSIS Brem. sp. nov.

Series *Pubicrurium*, maxime ut *H. cumingiana* (Nees) F.- Vill. sed statura minore, foliis basi inaequalibus, bracteis minoribus, granulis pollinis non carunculatis, virgis 21 ornatis ab ea certe diversa.

Herba erecta, simplex vel parce ramosa, circ. 15 cm alta, caule probabiliter post anthesin decumbente et e nodis caules novellos emittente. Caulis ramique primum pilis recurvatis dense pubescentes, postea glabrescentes, circ. 1 mm diam. Folia petiolo 0.7–1.6 cm longo, dense pubescentes, postea glabrescentes, lamina ovato-oblonga, 3.5–5 cm longa et 1.5–2.2 cm lata, apice subobtusata, basi inaequali, utroque latere rotundata sed prope petiolum subito contracta, margine haud profunde sinuosa et vix conspicue recurvata, tenuis, discolor, supra setulis paucis sparsa, opaca, subtus costa nervisque pubescens, cystolithis utrimque numerosis praesertim supra valde conspicuis, nervis utroque latere costae 3–4. Spicae terminales et in axillis foliorum supremorum plerumque solitariae. Pedunculi 2–4 mm longi, pubescentes. Rachis puberulo-pubescens. Bractee infimae ovato-lanceolatae, 7.5 mm longae et 3.5 mm latae; aliae lanceolatae, 6 mm longae et 2.5 mm latae; omnes subacutae, margine et costa breviter ciliatae, ceterum subglabrae. Calycis lobi 8–9 mm longi, margine et costa pilis brevibus, apicem versus cum pilis aliquibus paulo longioribus mixtis ciliati. Corolla alba circ. 16 mm longa, lobis extus pubescentibus. Stamina antheris apice obtusis, thecis basi obtusis. Granula pollinis 21 virgis punctatis ornata, 40–45 μ longa et 35–40 μ diam. Ovarium ad apicem hirtellum, utroque loculo ovulis 4. Stylus brevissime hirtellus. Capsula glabra, 8-seminalis.

POLILLO ISLAND, N. E. Polillo, Karlagan, alt. 30 m. *Philip. Nat. Herb.* 8953 Robert B. Fox (type), "in forest."

This species differs from the other members of the *cumingiana* group by its small size and by its conspicuously unequal leaf base, one-half of the leaf being distinctly longer than the other one.

HEMIGRAPHIS PARVIFOLIA Brem. sp. nov.

Series *Nudicrurium*, maxime ut *H. sublobata* Elm. sed caulibus ramisque pilis brevibus recurvatis vestitis, pedunculo glabro tamen ab ea recedit.

Herba parva repens, ramis floriferis brevibus ascendentibus. Caules ramique graciles, 0.4–0.6 mm diam., primum pilis recurvatis brevibus dense pubescentes, deinde plus minusve glabrescentes. Folia petiolo gracili, subtus pilis recurvatis brevibus dense pubescente, supra glabro, 5–10 mm longo instructa; lamina oblonga vel ovato-oblonga, 0.7–2.2 cm longa et 0.4–1.0 cm lata, obtusa, basi prope petiolum breviter contracta, margine irregulariter repanda, tenuis, cystolithis utrimque distinguendis, supra saturate, subtus dilute viridis, supra glabra vel interdum pilis perpaucis sparsa, subtus costa nervisque densius puberulo-pubescentis, nervis utroque latere costae 2–4. Spicae pedunculo gracili glabro, 0.4–2.0 cm longo instructae; rachis glabra, 1–7 mm longa, 2 vel 3 paribus florum instructa. Flores infimi interdum foliis parvis et angustis usque ad 10 mm longis suffulti; alii bracteis spatulatis 5–6 mm longis, subglabris. Flores in axillis bractearum solitarii, ebracteolati. Calyx 6–9 mm longus; lobi primum costa et margine hirtelli, deinde plus minuve glabrescentes. Corolla dilute violacea, 15 mm longa. Stamina longiora filamentis in alas hirtellas decurrentibus; antherae apice obtusae, thecis basi muticis. Granula pollinis magnitudine valde inaequalia, usque ad 48 μ longa et 39 μ diam., virgis 24 instructa. Ovarium comosum, utroque loculo ovulis 6. Stylus basin versus hirtellus. Capsula glabra vel apice pilis paucis sparsa; semina usque ad 12.

MINDANAO, Surigao Province, Mt. Kabatuan, alt. 600 m. *Philip. Nat. Herb.* 10504 D. Mendoza and P. Convocar (type), "on rock in forest slope."

As stated above this species comes nearest to *H. sublobata* Elm. but its leaves are smaller and the indumentum is different.

HYPOESTES PSILOCHLAMYS Brem. sp. nov.

Ex affinitate *H. laxiflorae* Nees, *H. cinereae* C. B. Clarke, *H. vidalii* C. B. Clarke, sed ab omnibus involucris glabris distinguenda.

Herba robustior. Rami obtuse quadrangulares, internodiis usque ad 7 cm longis et 4 mm diam., bisulcatis, ad nodos sparse pilosi, ceterum glabri, isophylli. Folia in petiolum glabrum, 1–2.5 cm longum contracta; lamina ovata vel ovato-lanceolata, 4.5–11 cm longa et 2.5–5 cm lata, apice acuta vel subcontracta, calloso-mucronata, basi contracta et sensim in petiolum vergens,

marginē integra vel vix conspicue crenata, costā subtus sparsissime pilosa, ceterum glabra, tenuis, discolor, sicc. fuscens, cystolithis parvis, subtus plerumque inconspicuis, supra vix conspicuis, costā supra canaliculata, nervis utroque latere costae circ. 8. Capitula in spicas quae in paniculum amplum confluent disposita; ramuli paniculi foliis minoribus suffulti; pedunculus internodio precedenti subaequalis, internodio rachidis sequente paulo longior. Capitula solitaria ad nodos spicarum. Bractee capitula suffulcientes subulatae, 2.3–3.5 mm longae, bracteis vacuis cum quibus vagina brevī connatae sunt paulo longiores, glabrae. Involucrum 9–10 mm altum; foliola dua externa 6 mm connata, hyalino-marginata et marginē puberulo-pubescentia, ceterum glabra, costata et cystolithis conspicue lineolata, acuta; foliola dua interna circ. 1 mm breviora, ceterum externis similiora. Calyx 6 mm longus, tubo 4 mm longo, lobis quattuor 2 mm longis, quorum uno apice breviter bilobato, aliis paulo latiore, omnibus marginē ciliolatis. Corolla purpurea, 2.2 cm longa, extus pubescens, tubo 10 mm longo, labio inferiore 4.5 mm lato, lobis 3 rotundatis 1.2 mm longis, labio superiore 1 mm lato, integro, obtuso. Stamina filamentis unifariam hirtellis, 10 mm longis, antheris ovoideis 2 mm longis. Granula pollinis pro genere breviora, 53 μ longa et 33 μ diam. Discus e lobis ovatis 2 circ. 1.2 mm longis compositus. Ovarium glabrum. Stylus glaber, 1.5 cm longus; stigmata 2 vix 0.5 mm longa. Capsula glabra, 9 mm longa, valvulis dorso profunde sulcatis.

LUZON, Mountain Province, Mt. Pulog, Kabayan, alt. 2,000 m. *Philip. Nat. Herb.* 4384 M. Celestino, A. Castro and P. Añonuevo (type), "open field"; Bataan Province, Mt. Kuyapo, alt. 1,400 m. *Philip. Nat. Herb.* 4150 G. E. Edaña; Bulacan Province, Polo, *Phil. Nat. Herb.* 4270 D. R. Mendoza.

This species is easily distinguishable from its nearest allies by the almost entirely glabrous involucre. The latter are only along the hyaline margin slightly puberulo-pubescent.

CALOPHANOIDES PUBESCENS Brem. sp. nov.

C. dispari (Merr.) Brem. n. comb. v. infra valde affinis, sed ramis ramulisque dense pubescentibus, foliis minoribus costā nervisque pubescentibus, floribus paulo minoribus, capsula dimidio breviorē ab ea facilliter distinguenda.

Herba valde ramosa. Rami subteretes, dense pubescentes, usque ad 2 mm diam., internodiis usque ad 6 cm, in parte floriferarum tamen circ. 1 cm longis. Folia petiolata, quoque pari inaequalia; petiolus dense pubescens, foliorum majorum

2–6 mm, foliorum minorum 1–4 mm longus; lamina ovata vel elliptica, foliorum majorum 1.8–3.5 cm longa et 1.2–2.0 cm lata, foliorum minorum 0.8–1.9 cm longa et 0.5–1.2 cm lata, semper apice subacuta, basi contracta, margine subintegra, tenuis, discolor, sicc. supra saturate olivacea, supra costa densius, alibi sparse hirtella, subtus praesertim costa nervisque pubescens, nervis utroque latere costae in foliis majoribus plerumque 4, in foliis minoribus 3, reticulatione subtus plerumque calore saturatiore conspicua. Flores in axillis solitarii, raro duo superpositi, subsessiles. Bracteolae florum in axillis foliorum majorum insertorum ovatae, circ. 0.5 mm longae; bracteolae florum in axillis foliorum minorum insertorum spatulatae et usque ad 4 mm longae. Calyx pubescens; lobi 5–6 mm longi, carinati. Corolla alba, extus glabra, 8 mm longa; labium inferius 4 mm latum. Stamina filamentis glabris 3 mm longis, in costas hirtellas decurrentibus, thecis ambobus calcaratis. Granula pollinis 30 μ longa, 18 μ lata, 15 μ crassa. Ovarium basi disco 2-lobo circumdatum, dimidio superiore puberulum, 1.8 mm altum. Stylus subglaber, 5 mm longus. Stigma didymum stylo vix conspicue crassius. Capsula 5 mm longa, apice puberula.

LUZON, Batangas Province, Mt. Lobo, alt. 350 m. *Philip. Nat. Herb.* 8573 M. D. Sulit (type), "abundant in the forest."

The genus *Calophanoides* Ridl. was based on *C. quadrifaria* (Nees) Ridl. (*Gendarussa* et *Adhatoda* Nees). It was discussed by me at some length in Verh. Kon. Ned. Akad. v. Wetensch., Afd. Natuurk., Sect. 2, 45² (1948) 56. To the two species recognized by Ridley, viz. *C. quadrifaria* (Nees) Ridl. and *C. neesiana* (Nees) Ridl. (*Adhatoda* Nees) I added the Javan *C. zollingeriana* (Nees) Brem. (*Adhatoda* Nees) and the Philippine *C. loheri* (C. B. Clarke) Brem. (*Justicia* C. B. Clarke). The genus, however, proves to comprise some more species, for *Justicia salicifolia* T. And., a plant from Khasia, will have to be transferred also to this genus, and in the Philippines there are three more species. One of them is the *C. pulgarensis* (C. B. Clarke ex Merr.) Brem. mentioned in this paper as one of the species represented in the collection, and the two other ones are *C. addisoniensis* (Elm.) Brem. n. comb. [*Hypoestes* Elm., Leaflet. Philip. Bot. 5 (1913) 1697; *Polytrema addisoniense* (Elmer) comb. nov. in Philip. Jour. Sci 10C (1915) 341; *Hallieracantha addisoniensis* Merr. n. comb. Enum. Philip. F. Pl. 3 (1923) 483] and *C. dispar* (Merr.) Brem. comb. nov. [*Justicia* Merr. in Philip. Jour. Sci. 13C (1918) 62. *Hallieracantha ad-*

disoniensis (Elm.) Merr.] was reduced by van Steenis in Bull. Jard. Bot. Buitenzorg (1948) p. 396 to *Calophanoides quadri-faria* (Nees) Ridley, but in view of its glabrousness and of the shortness of the calyx lobes it seems better to retain this species, at least until more abundant material becomes available.

The Philippine species of *Calophanoides* are easily distinguishable. *C. addisoniensis* and *C. loheri* have narrow leaves; in the first species they are lanceolate and in the second linear or, occasionally, linear-lanceolate; the leaves of *C. addisoniensis*, moreover, assume in dried material a dark colour, whereas those of *C. loheri* remain green. *C. pulgarensis*, *C. dispar* and *C. pubescens* have wider leaves, viz. ovate-oblong, ovate or elliptic ones. Those of *C. pulgarensis* are subequal and much larger than those of *C. dispar* and *C. pubescens*, for they are on the average 7 cm long and 4 cm wide, whereas in *C. dispar*, which is like *C. pubescens* a heterophyllous species, the larger leaves are 4 to 6 cm long and 2 to 3 cm wide, and the smaller ones 1 to 2 cm long and at the most 1 cm wide. The leaves of *C. pubescens* are smaller not so markedly unequal as those of *C. dispar*, for the larger ones are here 1.8 to 3.5 cm long and 1.2 to 2 cm wide, whereas the smaller ones vary in length between 0.8 and 1.9 cm and in width between 0.5 and 1.2 cm. *C. pubescens* differs moreover conspicuously from *C. dispar* in the presence of a dense pubescence on its shoots and petioles.

THE PHYSIOLOGICAL AVAILABILITY OF CALCIUM,
PHOSPHORUS, AND NITROGEN FROM THE BONES
AND FLESH OF DILIS, A SMALL FISH USED
IN THE FILIPINO DIET¹

BY RUTH M. LEVERTON

*Of the University of Nebraska; Fulbright Professor in Nutrition,
assigned to the Philippine Women's University, Manila
for the school year 1949-1950.*

and

SOLEDAD RAMOS PAYAWAL

Of the Institute of Science and Technology, Manila

The superiority and prestige of milk as a source of calcium has resulted in other sources of this important mineral being unappreciated and neglected when dealing with food problems of countries where milk is not in abundant supply.

The diet of Filipinos as of other Oriental groups is extremely deficient in calcium when judged by milk consumption. Although many of the diets contain no milk they support growth, though at a subnormal rate.

Basu and co-workers (1942) have studied the metabolism of men on the typical rice-and-fish and rice or wheat-and-vegetable diets of India. They measured the availability of the calcium ingested in the process of chewing betel-leaves with lime and in eating small fish including the bones. In the first study the daily calcium intake on the basal diet averaged 349 mg. and when this was increased by 371 mg. by chewing 6 betel-leaves with lime the daily retentions increased from -75 to 130 mg. In the other study the basal diet furnished 200

¹ Published with the approval of the Director, as paper no. 525 Journal Series, Nebraska Agricultural Experiment Station. The study was made possible by the cooperation of the U. S. Educational Foundation in the Philippines, Philippine Women's University, the Institute of Science and Technology, the National Research Council of the Philippines, the Institute of Nutrition, and the United Nations International Children's Emergency Fund.

mg. calcium daily to which was added a daily supplement of 70 mg. of a variety of small fish, including bones, to increase the daily calcium intake by 577 mg. On the basal diet the average daily retention was -118 mg. and this was changed to +267 mg. when the fish was added. The retentions in both studies compared favorably with that when the diet was supplemented with 10 oz. of cow's milk. The authors conclude that both the lime and the bones of small fish are cheap and effective sources of calcium.

Fish is a common item in the Filipino diet, particularly among people with low incomes. It is the chief source of animal protein and is eaten fresh, dried, or smoked. One small fish in particular is eaten whole, including the bones. It is called "dilis" in Tagalog, or "long jawed anchovy" in English, (*Stolephorus commersoni* of the Family Engraulidæ).

In isolated inland farms and barrios where fresh fish is not available, it is the common practice for a family to stock up on dried dilis, other dried fish (tuyo, daing), and smoked fish (tinapa) to use when other foods are not available or cheap in the markets.

The present study was undertaken to evaluate this fish, whole dilis including the bones, as a source of calcium especially but also of phosphorus and nitrogen, for children by comparing the availability of these nutrients from dilis with their availability from milk.

PROCEDURE

The study was conducted in a child-care institution in Manila. Eight Filipino girls ranging in age from 9½ to 13 years served as subjects for eighty days from mid-January until early April of 1950. The children were considered "fine and healthy" by the local lay standard but they had many scars and manifestations of malnutrition which were apparent to the trained observer. No girl in the group had reached the menarche.

The general plan of the study and the dietary regimen are shown in Table 1. There are five periods designated as A, B, C, D, and E, and metabolism data were collected for the last five days of each period.

TABLE 1.—*Plan and dietary regimen*

Period	Number of days		Diet
	Fore-period	Metabolism	
A	(1)	5	Usual institution diet.
B	17	5	Usual institution diet with enriched rice replacing non-enriched rice and with daily supplements of: 500 ml. whole milk ² 75 mg. ascorbic acid. 5,000 I. U. vitamin A
C	8	5	Same as Period B except that 20 gm. dried powdered fish (dilis) replaced the 500 ml. whole milk.
D	17	5	Same as Period C (calcium from dilis).
E	9	5	Same as Period B (calcium from milk).

¹ All children had been on institution diet at least seven months.

² Reconstituted evaporated milk with vitamin D added.

The kind and amount of food served to all the children in the institution varied so slightly from day to day that it was possible to have the usual meals serve as a basal diet. Rice was the main item in the diet. The girls in this study had an average daily consumption of approximately 260 gm. rice (uncooked weight) plus a small amount of fish or meat and fruit or vegetable. Dried skim milk was provided by the UNICEF program and during period A each subject had the usual morning cocoa which contained approximately 2/3 cup of reconstituted milk. This was omitted in subsequent periods.

Because all of the girls were accustomed to being served the same amount of food this practice was continued. During the five-day metabolism periods all the food for each girl was weighed and seldom was there any uneaten food to be weighed and deducted from the original serving. Between metabolism periods all the children were served with portions of similar size but only one child's portions were weighed and recorded.

Period A was the control period with the subjects on the usual institution diet. During periods B, C, D, and E the diet was supplemented as follows to approach the dietary allowances recommended by the National Research Council of the Philippines. Enriched polished rice ² replaced the usual polished rice. A liver oil capsule containing 5,000 I.U. of vitamin A was given with the breakfast; a 50 mg. tablet of ascorbic acid was given

² The enrichment formula included 2 mg. of thiamine, 15 mg. of niacin, and 13 mg. of iron per pound of rice.

with the noon meal, and a 25 mg. one with the evening meal. During periods B and E 500 ml. of whole milk were added, 250 ml. were served with the breakfast and 250 ml. for the mid-afternoon lunch. During periods C and D 20 gm. of powdered dilis replaced the milk on an iso-calcium basis, 7 gm. were served in each breakfast and dinner and 6 gm. in supper. This amount was weighed into individual paper dishes and the subjects mixed it with their rice or ate it plain, whichever they chose. A comparison of the nutritive value of the milk and dilis is shown in Table 2.

TABLE 2.—*Comparison of nutritive value of milk and dried dilis*

Nutrient	Milk 500 ml.	Dried dilis 20 gm.
Calcium gm.....	.66	.66
Phosphorus gm.....	.49	.47
Nitrogen gm.....	2.80	2.25
Calories.....	345.00	53.00
Thiamine mg.....	.18	*
Riboflavin mg.....	.90	*

* Values not available

The powdered dilis used in the study was prepared as follows: Fresh dilis were cleaned by removing the intestines, then soaked in 10 per cent brine for 30 minutes, and drained. To soften the bones, they were processed in a pressure cooker for 45 minutes at 15 lbs. The processed dilis were then dried in an infra-red dryer and ground to a fine powder. The percentage moisture was 10.9.

During metabolism periods A and B each food eaten was analyzed separately, but during each of periods C, D, and E 5-day food composites were made. Urine and fecal collections for each subject were made into 5-day composites and preserved with acid. Carmine was used to mark the stools. All the biological materials were analyzed for nitrogen by the macro-Kjeldahl method. Aliquots of the acid digests of food and feces were ashed for calcium and phosphorus determinations, but these determinations were made on unashed urine. Calcium was determined by the method of McCrudden as modified by Stearns, (1929), and phosphorus by the method of Fiske and Subbarow (1925) using a photoelectric colorimeter.

Hemoglobin and serum protein values of the blood and the thiamine : creatinine ratio were determined at the beginning

and the end of the study.³ Blood was taken from a freeflowing finger puncture. Creatinine was determined on a rising sample of urine.

The girls had been treated and freed from intestinal parasites eight weeks prior to period A but when tested at the end of period A they were found to be re-infected with *Ascaris* and/or *Trichuris*. Immediately following period B they were again treated and freed but reinfection may have occurred before the end of the study.

RESULTS

In Table 3 are shown the means and their standard errors for the daily intake, excretion, and retention for calcium, phosphorus, and nitrogen of the eight subjects for each of the five-day periods.

Calcium.—During the control period on the low daily intake of 0.30 gm. of calcium, the mean retention was 0.07 gm. In only one of the eight subjects did the excretion exceed the intake significantly. When in period B the intake was increased to 0.98 gm. by the addition of 500 ml. of milk and the diet improved in other respects the mean daily calcium retention for the group rose from 0.07 to 0.45 gm. per day. In periods C and D, when the milk was replaced by 20 gm. of powdered dilis the mean daily retention was 0.36 and 0.31 gm. respectively. In period E, when milk replaced the dilis, the mean daily calcium retention was 0.35 gm. Analysis of variance showed that the differences in retentions which occurred between periods B, C, D, and E were not significant. No subject had a negative retention in these last four periods. There was no relation between the ages of the children and the amount of calcium retained.

Phosphorus.—During the control period on daily intake of 0.35 gm. of phosphorus each of the eight subjects had an excretion of phosphorus which exceeded the intake and the mean daily retention for the group was -0.21 gm. When the phosphorus intake was increased in subsequent periods to 1.09, 1.14, 1.05, and 1.02 in periods B, C, D, and E respectively, daily retentions varied from 0.35 for period B to 0.29, 0.21, and 0.13

³ The authors are indebted to Mrs. Carmen Ll. Intengan and Mrs. Dulce Laurel-Bacobo of the Institute of Nutrition, Manila, for the blood and thiamine: creatinine determinations.

in the following periods. Phosphorus retentions decreased or levelled off as the length of time on the improved phosphorus intake increased. Variations in retentions were not related to age of the subjects.

TABLE 3.—Mean daily metabolism data for 8 subjects for 5 periods

Nutrient	Period									
	A		B		C		D		E	
	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.
	gm.		gm.		gm.		gm.		gm.	
Calcium:										
Intake	0.30		0.98		0.96		0.95		0.93	
Excretion	0.23	.023	0.53	.055	0.60	.063	0.64	.047	0.58	.031
Urine	0.05	.008	0.04	.008	0.08	.018	0.07	.015	0.06	.009
Feces	0.18	.028	0.49	.055	0.52	.062	0.57	.054	0.52	.032
Retention	0.07	.023	0.45	.055	0.36	.063	0.31	.047	0.35	.031
Phosphorus:										
Intake	0.35		1.09		1.14		1.05		1.02	
Excretion	0.56	.034	0.75	.041	0.85	.081	0.84	.040	0.89	.028
Urine	0.32	.017	0.48	.020	0.47	.038	0.47	.032	0.53	.027
Feces	0.24	.021	0.27	.031	0.38	.038	0.37	.034	0.36	.017
Retention	-0.21	.034	0.35	.041	0.29	.081	0.21	.040	0.13	.028
Nitrogen:										
Intake	6.04		8.19		8.28		8.22		8.52	
Excretion	5.85	.368	6.73	.353	6.85	.337	6.91	.342	6.61	.229
Urine	3.83	.241	5.09	.254	5.27	.367	5.32	.317	4.84	.207
Feces	2.02	.065	1.64	.162	1.58	.103	1.59	.073	1.77	.085
Retention	0.19	.368	1.46	.353	1.43	.337	1.31	.342	1.91	.229

Nitrogen.—During the control period on a daily nitrogen intake of 6.04 gm., 2 subjects had negative retentions but the mean for the group was a daily storage of 0.19 gm. nitrogen. When the daily nitrogen intake was increased to 8.19, 8.28, 8.22 and 8.52 in periods B, C, D, and E respectively the daily retentions increased markedly and averaged 1.46, 1.43, 1.31, and 1.91 respectively for these periods. The slightly higher nitrogen intake during period E may account for the higher retention.

Utilization.—In Table 4 is shown the mean percentage utilization of calcium, phosphorus, and nitrogen from the milk and from the dilis. The utilization was above 35 per cent for calcium and above 50 per cent for phosphorus and nitrogen. Small differences in intake caused some of the variation. Calcium and phosphorus were utilized to the greatest extent in period B when the diet was first improved. The percentages are slightly higher for utilization from milk than from dilis but the differences cannot be considered significant because the absolute retention were not significantly different and because the subjects were in a depleted state.

The mean hemoglobin and serum protein values together with the thiamine : creatinine ratio in the urine of all subjects at the beginning and at the end of the study are shown in Table 5. The mean serum protein level remained unchanged; the hemoglobin value increased 0.6 gm. per 100 ml. blood; and the thiamine : creatinine ratio increased almost ten-fold, from 45 to 438 ug. thiamine per gram of creatinine.

TABLE 4.—*Mean percentage utilization of additional calcium from milk and from dilis by all subjects*

Period	Source of calcium	Percentage utilization*		
		Cal-cium	Phos-phorus	Ni-trogen
A				
B	Milk	55.9	75.7	59.1
C	Dilis	43.9	63.3	55.3
D	Dilis	36.9	60.0	51.4
E	Milk	44.4	50.7	69.3

* Calculated from the formula:

$$\frac{\text{Intake period B, C, D, or F} - \text{Intake period A} \times 100}{\text{Retention period B, C, D, or E} - \text{Retention period A}} = \text{percentage utilization}$$

TABLE 5.—*Mean hemoglobin, serum protein, and thiamine : creatinine ratio for all subjects at beginning and end of study*

	Beginning of study		End of study	
	Mean	Range	Mean	Range
Serum protein grams per cent.-----	7.0	6.0-7.8	7.0	6.4-7.6
Hemoglobin grams per cent.-----	13.2	11.4-14.5	13.8	12.0-15.3
Thiamine: creatinine ratio micrograms per gram-----	45.00	16.0-65	428.00	295.0-656

As would be expected the girls improved in appearance and energy during the period of dietary supplementation. Between January 22 and April 5 their gains in weight ranged from 1.4 to 4.0 kg. and averaged 2.4 kg. for the group. Gains in height ranged from 1.2 to 2.4 cm. with an average of 1.8 cm. Comparison of these gains with gains on unsupplemented diets was not possible.

DISCUSSION

Both the absolute retention and the percentage utilization of calcium by these eight girls were high, and reflected their deficiency status prior to the periods of improved intake. Be-

cause the subjects' metabolism was not static but was being constantly influenced by the gradual recovery from deficiencies of long standing comparisons of these findings reported in the literature are not practical.

The mean calcium retentions of the girls in this study varied from 0.45 to 0.31 gm. which were greater than the amounts which are considered necessary for children 9 to 13 years. Based on skeletal growth, Venar and Todd (1933) have calculated that a storage of 157 mg. calcium daily is necessary for a 9-year old child and that this amount decreases gradually to 138 mg. for a 13-year old. On the other hand, Mitchell and Curzon (1939) who consider that skeletal weight is a constant fraction of total weight have calculated a daily retention requirement of 110 mg. at 9 years increasing gradually to 201 mg. at 13 years.

In a review of calcium metabolism by Holmes (1945) it is stated that a pre-school child can utilize about 20 per cent of the total dietary calcium ingested, an adult about 30 per cent, and the school-age child some amount between these two. On the institution diet the subjects utilized 23 per cent and on the adequate diet from 33 to 46 per cent of the total ingested calcium.

The spectacular increase in the thiamine : creatinine ratio in the urine from 45 to 428 ug. per gram as a result of the replacement of ordinary polished rice with enriched polished rice indicates the effectiveness of enriching rice with thiamine. The daily thiamine intake in period A was probably less than 0.2 mg. whereas, during periods B through E the average daily intake of 260 gm. of enriched rice (uncooked weight) meant an increase of 1.1 mg. in the thiamine intake.

Burch, et al. (1950) found an average urinary excretion of 47.3 ± 3.1 ug. thiamine per gram of creatinine in 20 adults with frank and suspected beri-beri and 71.4 ± 4.4 ug. per gram in 20 non-symptomatic adults. At the beginning of the present study the children had thiamine:creatinine ratios which ranged from 16 to 65 ug. per gram and averaged 45 ug., a figure almost identical with that found by Burch in adults with frank and suspected beri-beri. The children demonstrated symptoms of fatigue, listlessness, and some nervous disturbances, but no frank beri-beri.

The widespread use of dilis in the Filipino diet has meant a nutritional value which was not apparent when the diets were judged by the dietary standards used in the United States.

In the vital effort to improve the quantity and quality of food for the world's population there is increasing need for specific evaluation of food characteristic of different localities and cultures. Even though an indigenous food may not be utilized as well physiologically as some food which is considered nutritively essential in the U. S. diet, the indigenous food may be more acceptable and available locally and thus more valuable to the people than a food of superior nutritive value which is unattainable and perhaps non-acceptable. Moreover, in many parts of the world foods like fresh fluid milk, which require exceptionally sanitary handling and some form of refrigeration in order to be preserved for even a day, may prove dangerous as well as expensive and impractical. Such considerations affect the diet of nations like the Philippines far more than most Americans realize.

SUMMARY AND CONCLUSIONS

For 80 days early in 1950, eight Filipino girls between the ages of 9½ and 13 years served as subjects for a study of the availability of calcium and phosphorus and nitrogen from the small fish, dilis, eaten whole including the bones, as compared with the availability of these nutrients from milk.

Metabolism data are presented for the subjects for five 5-day periods: period A when the subjects were on their usual diet which was inadequate, period B on an adequate diet including 500 ml. whole milk, periods C and D on the adequate diet with the milk replaced by the dried powdered dilis, and period E on the adequate diet with milk.

Calcium retentions for all subjects were high on the improved diet. The mean for the group for each period B through E, ranged from 0.45 to 0.31 mg. and the differences between periods were not significant. The mean daily phosphorus retentions decreased gradually from 0.35 gm. for period B to 0.13 gm. for period E.

Mean nitrogen retentions on the adequate diet ranged from 1.31 to 1.91 gm. and the differences between periods were not statistically significant.

The replacement of polished rice with enriched polished rice during periods B through E increased the mean thiamine : creatinine ratio of all subjects from 45 to 428 ug. per gram.

From results of this study it appears that girls of this age can utilize the calcium, phosphorus, and nitrogen from the bones and flesh of dilis as well as from milk.

ACKNOWLEDGEMENT

The authors wish to express sincere appreciation for the co-operation of Miss Maria Lardizabal and her staff at Settlement House, where the study was conducted, and for the assistance of Estelita Moreno, Josefina Manalo, Salud Fajatin, Timotea Gako, Jovita Pilapil, and Pooh Gamboa.

REFERENCES

- BASU, K. P., M. N. BASAK and H. N. DE. Availability of calcium ingested in the process of chewing betel-leaves with lime. *Ind. Jour. Med. Res.* **30** (1942) 309.
- BASU, K. P., H. NADE and M. N. BASAK. The bones of small fish as a source of nutritionally available calcium and phosphorus. *Ind. Jour. Med. Res.* **30** (1942) 417.
- BURCH, H. B., J. SALCEDO, JR., E. O. CARRASCO, C. L. INTENGAN and A. B. CALDWELL. Nutrition survey and tests in Bataan, Philippines. *Jour. Nutr.* **42** (1950) 9.
- FISKE, C. H. and Y. SUBBAROW. The colorimetric determination of phosphorus. *Jour. Biol. Chem.* **66** (1925) 375.
- HOLMES, J. A. The requirement for calcium during growth. *Nutr. Abs. and Rev.* **14** (1945) 597.
- MITCHELL, H. H. and E. CURZON. Actualites scientifiques et industrielles No. 771, *Nutrition* **18** (1939) 199.
- STEARNS, G. A rapid method for the preparation of fecal digests suitable for use in nitrogen and mineral analyses. *Jour. Lab. and Clin. Med.* **14** (1929) 954.
- VENAR, Y. A. and T. W. TODD. White House Conference on child health and protection 2. *Anatomy and Physiology*. New York, 1933. p. 93.

OBSERVATIONS ON MANSON'S TAPEWORM, DIPHYLLO
BOTHRIUM ERINACEI RUDOLPHI, 1819, IN THE
PHILIPPINES ¹

BY LOPE M. YUTUC

*Of the College of Veterinary Medicine, University of the
Philippines*

THREE PLATES

The Pseudophyllidean tapeworms are represented by two families with five genera in the Philippines. Of these five genera the most important genus is *Diphyllbothrium* Cobbold, 1858. In the Philippines this genus has two species, namely *Diphyllbothrium latum* and *Diphyllbothrium erinacei*. The latter is the subject of the present contribution. The tapeworm was first reported in the Philippines by Wharton (1917) and referred to, by him, as *Dibothriocephalus* sp. Its specific identity remained indefinite for sometime, until Tubangui (1938) recorded it as *Diphyllbothrium mansonii* (Cobbold, 1883). However, the above nomenclature was not adapted in this paper, instead the writer chose *Diphyllbothrium erinacei*,² due principally to the experimental and morphological observations of Iwata (1933) and later Joyeux, Houdemer and Baer (1934).

This Pseudophyllidean cestode has a wide geographical distribution. It is common in the Orient. It has also been reported in British Guiana, Australia, Holland, Africa and Texas and Florida, United States. Although the first intermediate host of the tapeworm is exclusively confined to various species of cyclops, the second intermediate hosts are varied and many, consisting of species of amphibians, reptiles, avians and mammals. The adult worm has been recorded in dogs, cats, foxes, lions, tigers, leopards and racoon dogs.

¹ Data of this paper were obtained principally during the Japanese occupation.

² This has been confirmed by Mr. Allen McIntosh, through the kindness of Dr. Benjamin Schwartz, Zoological Division, Bureau of Animal Industry, Washington, D.C.

For many years this tapeworm was known only in its larval stage, the plerocercoid. The credit of having first discovered it is generally given to Sir Patrick Manson. In 1882 he found it during an autopsy on a Chinese in Amoy, South China. However, Iwata disclaimed this fact and instead credited Scheube (1881) for having first found the larva in the Kyoto hospital in Japan. In the Philippines, Ira-Concepcion (1935) reported the occurrence of what appeared to be a sparganum in the superficial connective tissue of a student residing in Manila.

A survey of the literature on *Diphyllobothrium erinacei* in the Philippines disclosed that only fragmentary investigations have been carried in spite of the fact that it is not only a veterinary but also a public health problem. In view of this circumstance the present observations were undertaken with the main object of supplementing the present knowledge of the parasite in question.

LIFE HISTORY

Ova were collected from the feces of infected cats and dogs by screening and sedimentation. Measurements taken on the average were 0.057 mm long and 0.034 mm wide with a slight yellowish to yellowish brown tinge (Pl. 1, fig. 1). To remove the debris and large particles of feces that had remained, a small jet of water was fed to the petri disc. Afterwards, the egg-culture was divided and placed in a petri disc and kept at room temperature. Since the embryo was entirely formed within the egg-shell at the end of the seventh day (Pl. 1, fig. 2), theoretically, the egg was ready to hatch at that time. In actual experience, however, variable results were encountered. For example, in one instance at the end of the seventh day the petri disc containing the egg-culture was already literally swarming with coracidia and at another it took nine to ten days (Pl. 1, fig. 3). At this time the cyclops were introduced into the cultures. Eight days later some cyclops were dissected and elongated oncospheres were found (Pl. 1, figs. 4 and 5). They moved sluggishly in the microscopic field by means of extension and contraction. During contraction they measured on the average 0.04 mm in length and 0.022 mm in width, at extension 0.06 and 0.014 mm in length and width respectively. At the end of the twelfth day they constricted off the cercomer and reached the length of 0.12 mm and the width of 0.03 mm. (Pl. 1, fig. 6). They assumed now the proceroid form. Shortly thereafter the calcareous corpuscles appeared. On the fourteenth day the final form and size appeared to be attained,

yet not infective. Actual measurements made showed the proceroid to have reached 0.15 mm in length and 0.05 mm in width (Pl. 1, fig. 7). Up to this stage the life cycle closely paralleled the works of Okumura (1919), Kobayashi (1931), Africa (1934) and Mueller (1938). After two more days the proceroids were used for infection experiments. Mice and frogs were employed but the results were not sufficiently encouraging. Further, the span of life of the cyclops seldom reached sixteen days in the petri disc culture and were frequently noted attacked with ectoparasitic growth such as bacteria, vorticella and so on, hence the procedure was modified. Instead of petri disc, two miniature aquaria were built where cyclops were reared and kept. When the water of the aquarium was already teeming with cyclops, seven-day old eggs of *Diphyllbothrium erinacei* were introduced into it. At appropriate intervals a number of cyclops were examined under cover-preparation for the larval diphyllbothrids. With the cyclops positive, from the fifteenth to the sixteenth day, ten tadpoles obtained from a water hole known to be free from plerocercoids by a previous survey were placed into each aquarium. After a week a number of the tadpoles were dissected and invariably the plerocercoids were found (Pl. 2, fig. 8). The infection of the tadpoles appeared intimately related with the feeding habit, devouring the debris that had accumulated at the bottom of the aquarium. The infected cyclops were generally weak and tended to set on the debris thus in this matter were swallowed. Some of the tadpoles were allowed to mature into frogs and afterwards killed and examined. One to two spargana were observed and collected in six of the ten frogs dissected. It should be noted that before introducing the embryonated eggs at least ten cyclops from each aquarium were checked for the presence of proceroid as a test in the sterility of the cyclops employed in the experiments. The tadpole infection experiment was repeated three times with identical results. The present observations agree quite closely with the life history work of Han (1941) in Java, using *Diphyllbothrium ranarum*. Moreover, this finding aptly supports the occurrence of the spargana in the frogs in the Islands which will be dealt with below. From the above evidence, it is clear that the frog is the principal second intermediate host in the Philippines, the infection being initiated mainly during the tadpole stage. The sojourn of the tapeworm in the cat and the dog is reserved and will be presented in the later part of this article.

INCIDENCE OF SPARGANA IN THE PHILIPPINE FROG

Of the 338 frogs examined, 41 were positive of spargana or an incidence infection of 12.1 per cent. These frogs came from Pandacan, Manila; Pasig, Rizal; Laguna; Lubao, Bacolor and San Fernando, Pampanga; and Labrador, Pangasinan. The larval cestode was not found in at least 35 frogs examined in a barrio of San Fernando, Pampanga. The degree of infection of the positively infected frogs with spargana ranged from one to as many as twenty-five. Among the localities where frogs were obtained, Laguna showed the highest degree of infection, being 15 positive out of 24 frogs examined.

DISTRIBUTION OF THE SPARGANA IN THE FROG

The spargana were found in six regions of the body of the frog, namely: abdomen, chest, dorsal, front legs including shoulder, lumbar and the hind legs. The larval parasite has been noted 24 times in 41 instances in the hind legs. In the abdominal region out of 41 positive frogs it was noted in 18 instances. The next region that showed a high incidence was the lumbar, being 10 out of the positive frogs examined. The least in frequency was the chest, only two times out of the 41 positive rana. Further, in the hind legs, a total of 63 spargana were collected, representing more than one third of a total of 162 spargana collected from 41 frogs. In the abdominal region 45 spargana were collected. The least in number of total spargana recovered was in the chests from where only two parasites were recovered. From the above figures, it may be safely stated that the spargana have a profound affinity in establishing themselves to the heavy muscles and subcutaneous tissues of the hind legs and the abdomen. In the experimental infection of the leopard frog with the sparganum of *Diphyllbothrium mansonoides*, Mueller (1938) stated that "the spargana apparently have a preference for the liver" (p. 305). In the above investigation, in no instance was a sparganum found in the liver of the native frogs examined. The predilection of the spargana to certain regions of the body as in the hind legs and abdomen is to some extent influenced by gravity. The same phenomenon was observed by Mueller in the infection of monkeys with the plerocercoids of *Diphyllbothrium mansonoides*.

OTHER ANIMALS EXAMINED

Besides frogs, two water snakes, *Lapemis hardwickii*, several skinks known locally as "bubuli," two bitterns, *Ixobrychus cin-*

namonseus,³ two snakes, *Natrix spilogaster*,⁴ and a number of wild rats were examined for spargana. One of the two bitterns was found positive with one sparganum buried in the muscles of the inner thigh. In a snake caught in the act of devouring a frog in Pandacan, Manila, 161 spargana were recovered on autopsy. The spargana were located in the posterior half of the body anterior to the tail. In another killed in San Juan, Rizal, the reptile yielded 120 spargana. If the average number of spargana collected from the two snakes can be used as an index in the number of frogs devoured and the intensity of frog infection presented in the survey considered typical in the vicinity where the snakes were caught, it can be stated that each reptile may have devoured approximately 300 frogs, or close this figure before they were killed. These cases cited above enrich *Diphyllbothrium erinacei* with two auxiliary intermediate hosts heretofore unrecorded in the Islands. Mueller (1937) reported the spargana of *Diphyllbothrium mansonoides* occurring in *Natrix* from Florida, United States, the incidence being 90 per cent.

ORAL TRANSFER OF SPARGANA

While it is generally accepted the world over that the spargana of the *Diphyllbothriidae*, exemplified in this particular case by *Diphyllbothrium erinacei*, possess the peculiar ability to pass through the gastro-intestinal wall and re-establish themselves in the tissues without changes of form, it seems desirable to run experiments to test whether the local strain will behave in the same manner. The oral transfer was carried on in mice, white rats, guinea pigs, rabbits, chicken, three species of fresh water fish, a monkey and wild rats in the present investigation.

Experiment 1.—September 20, 1941, two young mice (1 and 2) were given per os one sparganum each obtained from a frog. Nine days later, the sparganum was recovered on autopsy from each mouse. In the first mouse it was located in the muscles of the right side of the neck and in the second, embedded in the muscles of the right thigh.

September 29, 1941, mouse 3 fed orally with two spargana recovered from the above mice. October 7, it was found dead. On autopsy one sparganum was recovered in the sublumbar muscles under the peritoneum; other lost.

October 2, 1941, mouse 4 was fed 5 spargana with no scolices and mouse 5 given numerous pieces of spargana but likewise

³ and ⁴—Identified zoologically by Dr. Canuto Manuel of the National Museum.

without scolex. Killed and autopsied 10 and 15 days respectively later; results negative.

October 12, 1941, mouse 6 fed with two spargana, one of which was obtained from a chick artificially infected. November 5, or 25 days after infection, it was killed and on autopsy two spargana recovered; one located at the base of the neck and the other at the point of the shoulder blade.

October 20, 1941, mouse 7 was infected by the mouth with one sparganum obtained from a bittern. December 13, it was killed and the sparganum buried in the muscles of the chest was recovered.

October 19, 1943, mouse 8 was infected with 5 spargana recovered from a snake; killed December 16; found 4 spargana distributed as follows: one in the muscles under the neck, one in the muscles on the dorsal region and the two others located one under each scapula.

Of the six mice infected orally with spargana all were successful. In contrast with the two mice fed with "headless" spargana and pieces of the parasite without scolex only negative results were recorded. This supports the statement that the germinal center is located in the "head." Of the 12 spargana used in this series, 10 were recovered; the rest lost.

Experiment 2.—September 24, 1941, a male rat was given per os 4 spargana recovered from two frogs caught in the zacate field adjacent the College compound at Pandacan. October 13, the rat was killed and no spargana found but instead 4 *Cysticercus fasciolaris* were noted embedded in the liver.

A second rat was infected with 5 frog spargana, September 27, 1941; killed 20 days later 4 spargana recovered, distributed as follows: two in the inner side of the thigh in the subcutaneous tissue, one in the dorsal region and the last one free in the abdominal cavity. These were fed immediately to rat 3. On November 4, 1941, the same animal was superinfected with 10 spargana of frogs secured from Lubao, Pampanga. Thirteen days later, the rat was killed and 10 spargana recovered. One located in the abdominal cavity, the others not definitely recorded.

On November 4, 1941, rat 4 was infected with 12 spargana from frogs caught in Lubao, Pampanga. November 17, it was killed; 7 spargana recovered. The distribution in the body was as follows: one in the sublumbar region under the peritoneum, 3 buried in the femoral muscles; 2 in neck muscles and the last one in the facia under the skin of the dorsal region.

October 19, 1943, rats 5 and 6 were fed with 15 spargana each obtained from a snake. December 17, the female rat was killed and autopsied; 11 spargana found. The distribution follows: one in dorsal region of the neck close to the subcutaneous tissue; three in ventral region of the neck near its base; one in the muscles of the lateral side of the neck; three in the dorsal region under the upper end of the shoulder blade; two in the axillary region and one buried in the femoral muscles. Eleven days later, the male rat was killed. Of the 15 spargana given only 12 were recovered on post mortem examination distributed as follows: two noted in the lumbar region; one in the subcutaneous tissue at the base of the tail; one in the scrotal region; one under the scapula on the side of the chest and the last 4 buried in the inner muscles of the thigh.

Summarizing the results in the rat transmission experiment, of the 6 animals used one escaped infection due of undetermined cause. Whether or not the presence of *Cysticercus fasciolaris* has something to do with the negative result, only future observations will determine. Besides, of the 65 spargana used in this series only 44 were recovered with a loss of 21 parasites.

Experiment 3.—October 9, 1941, a guinea pig was infected with two spargana from a chicken artificially infected. Sixteen days later it was given another dose of 6 spargana obtained from a chick. November 27, 1941, it was killed and two spargana recovered, one in the liver and the other in the subcutaneous tissue on the side of the abdomen.

A young guinea pig 2 fed with 3 spargana, October 24, 1941. The day following the animal was given another dose of 25 spargana obtained from a frog caught in Labrador, Pangasinan. October 31, or 6 days later, the animal developed ataxia, unable to stand and much depressed with complete loss of appetite. November 1, it was found dead. Post-mortem examination revealed 12 spargana out of 28 given; the longest being 2 centimeters and the shortest 0.53 mm. Four were embedded in the walls of the stomach producing hemorrhages; one in the fascia in the region of the shoulder and the rest found free in the abdominal cavity.

From the last guinea pig used in the above experiment, it was demonstrated that the spargana penetrated the digestive tract in the stomach and entered the peritoneal cavity, then probably pierced the peritoneum and wandered through the musculature of the body where they embedded themselves. However, some pre-

ferred the subcutaneous tissue as noted elsewhere in the other experiments. Further, of the 36 spargana used 14 were recovered on post-mortem examination with a loss of 22 larval tapeworm.

Experiment 4.—November 1, 1941, a rabbit was infected with 12 spargana from a guinea pig that died as a result of infection experiment. Ten days later it was killed and posted; 5 spargana recovered. One found in the region of the croup and four in the fascia of the abdominal muscles. This experiment was repeated November 3. In this case the rabbit was fed 20 spargana. December 19, 1941, killed and on post mortem only two spargana were recovered; one under the peritoneum in the sublumbar muscles and the other in the fascia of the abdomen.

Of the 22 spargana used in this series 7 were found on necropsy and the rest lost.

Experiment 5.—October 2, 1941, three 2-week-old chicks were given 11 spargana each. The following day one chick developed leg weakness, could not stand; others apparently normal. October 12, the paralytic bird was noted dead and on autopsy one sparganum recovered in the fascia near the base of the head. The sparganum was alive but seemed stunted. October 18, the second chick noted unable to stand; killed and on autopsy one sparganum found in the peritoneal cavity near the liver. November 11, the last chick was killed with negative post mortem examination.

Concurrently another test was conducted, October 3, 1941, where three 2-week-old chicks were fed 10 spargana each. On the 8th day one was noted gaping; the next day it was found dead. Necropsy revealed two spargana, one subperitoneal in the lumbar region; other not definitely recorded. October 12, another bird found weak, hence killed and autopsy performed. One sparganum recovered in the fascia of the dorsal region. It was somewhat stunted. On October 25 the last chick developed leg weakness and killed. Six spargana found, distributed subperitoneally, one along the course of the small intestine and the other four very close to the gizzard.

Of the six chicks used one failed to catch the infection. Of the 63 spargana only 11 were able to establish in the body of the chicks. Further, the recorded spargana were in general stunted.

Experiment 6.—December 16, 1943, a small climbing perch, *Anabas testudineus*, was fed 4 spargana from a mouse artificially infected. Two days later another dose of 3 spargana was given.

January 19, 1944, it was autopsied but no sparganum recovered. This experiment was repeated with another climbing perch, feeding it with 5 spargana. The next day after infection 3 scolices were found in the water at the bottom of the aquarium. While one was moving sluggishly, the other appeared dead. At this time the fish was superinfected with 3 spargana. Thirty-six days after last feeding, the fish was killed. On post mortem no sparganum recovered.

December 28, 1943, two small mud fish, *Ophiocephalus striatus*, were fed 4 spargana each recovered from a white rat. The larger of the two fish vomited 2 spargana, 3 hours later. The next day it was found dead. On autopsy two scolices were found in the posterior chamber of the buccal cavity. Close inspection showed no indication of being alive, hence declared dead. January 29, 1944, the other fish was killed and on necropsy no trace of the sparganum noted.

September 14, 1950, one "hito," *Clarias batrachus*, was fed two spargana from a frog. The next day another two fish were fed three frog spargana each. Sixteen days later all were killed and autopsied, but no sparganum recovered.

All in all twenty-eight spargana were used in the fish feeding experiment but none recovered on post mortem examination except from one that died the day following infection. In this connection Refuerzo and Garcia (1936) stated that "A priori frogs, fishes and reptiles may be considered as secondary hosts which harbor the plerocercoid larvae in the Philippines as in other countries where this cestode is found." The above findings rule out the fish as a secondary intermediate host of *Diphyllbothrium erinacei*, as far as the experiments were performed. Moreover, this is supported by similar results recorded with *Diphyllbothrium ranarum* in Java (Han, 1941).

Experiment 7.—November 17, 1941, a male monkey was fed 17 spargana recovered from rats 3 and 4. Ten days later one sparganum obtained from a guinea pig was also given to the monkey orally. December 11, 1941, another dose of 5 spargana recovered from a rabbit was likewise administered. May 23, 1942, one sparganum was noted on close inspection under the skin in the chest region. February 10, 1943, or 450 days after initial infection, it was found dead in the morning without any previous indication of even indisposition. On autopsy twelve out of a total of 23 spargana administered were traced in the body of the monkey, distributed as follow: one was noted in the subcutaneous tissue of the back close to the shoulder blade;

five under the peritoneum of the ilioas muscles; one encysted in the omentum; one in the thigh muscles; one in the diaphragm and the last 3 in the perirenal region under the peritoneum. There was no change in form and appearance of the spargana collected except three which were slightly tinged with yellow pigment.

This experiment furnishes an evidence that the Philippine monkey is susceptible to oral infection with spargana of frog origin and points strongly towards the susceptibility of man.

Experiment 8.—November 2, 1944, a wild rat was fed three spargana of frog origin. November 27, the rat was killed and on autopsy it yielded three normal branching spargana (Pl. 2, figs. 10 to 12). Two were found in the right inner thigh under the subcutis and one under the shoulder blade.

July 11, 1946, a frog was caught by a cat. On dissection four spargana were recovered and kept over night in saline solution in the refrigerator. The next day these were fed to one of the three wild rats kept in captivity. The other two rats were killed and search for sparganum made but result negative. August 17, 1946, the rat was found dead and four spargana were collected on post mortem. One of them was "headless" and found in the abscess located in the upper shoulder joint, one in the thigh and the two anterior to the shoulder joint. The three intact spargana were fed immediately to one of the two young wild rats reared in the laboratory; the other kept as control. December 4, both rats were killed. In the infected rat the three spargana were recovered, one at the base of the head on the dorsal aspect while another in the ventral region and the third in the subcutaneous tissue on the ventral aspect of the neck near its base. All three were transferred orally to a wild rat. April 1, 1947, the rat died and only one sparganum was recovered from the inguinal region.

This experiment shows that wild rats are possible auxillary host of the sparganum of *Diphyllbothrium erinacei*. However, thus far, no specimen has been reported in this animal in the Islands under natural condition in spite of the extensive survey carried by Tubangui (1931) on the parasites of wild rats in the City of Manila and the sporadic search made by the present author on this animal. The finding of three apparently normal branching spargana is quite interesting. This is in agreement with the observation of Feng, Hoeppli and Chu (1938) in China where branching forms were found occasionally in otherwise

normal spargana from naturally and experimentally infected hamsters.

Chandler (1949) states that "the sparganum of the European species of *Diphyllbothrium erinacei* was found by Joyeux et al. to develop only in amphibian, although it could later establish itself when eaten in anything from fish to mammals, except birds. The Chinese species, on the other hand, develop more rapidly in mice than in frogs and the American *Diphyllbothrium mansonoides* fails to develop in frogs (?) at all but develops readily in mice" (p. 332). As a result of the present studies, the Philippine sparganum was found experimentally as well as naturally to infect white rats, mice, guinea pigs, rabbits, monkeys, chickens, wild rats, frogs, bitterns and snakes but not three species of fresh water fish.

DISTRIBUTION OF SPARGANA IN ARTIFICIALLY INFECTED ANIMALS

The sparganum has been located in 24 sites in the seven species of animals used in the transmission experiments. In all apparently 274 spargana were employed but actually only 199 were used. This is due to the fact that some spargana were used two or even three times in the oral infection experiments. It would have been ideal if the sparganum once used has been discarded. However, due to the limited supply of the spargana this was not possible. Further, since it is a well known fact that this larval parasite is resistant, passing it through laboratory animals will not essentially affect its ability to establish in another host. The distribution of the sparganum in the animal body was quite variable. The sites where it was found most were the thigh and next the abdominal cavity with 13 and 10 spargana respectively; the least being the base of the tail, intestinal coils, diaphragm, omentum, scrotum, neck, liver and the subcutaneous tissue at the dorsal surface of the head. The later location is unusual in the sense that it is the highest point the sparganum has established itself, the host being a bird. The influence of gravity as seen in the seat of location in the body of the frog is not marked.

From this disjointed finding of the sparganum in the body of the experimentally infected animals one can trace better than previously indicated in this paper, the possible route of the larval tapeworm until it resides and lives in the subcutaneous tissue or in the muscles of the body. At least in guinea pig No. 2

we found the spargana in the walls of the stomach preparatory to penetrate the wall into the peritoneal cavity. In two rats and one guinea pig the spargana were actually located free in the abdominal cavity. From here, the plerocercoid pierced again the peritoneal lining of the abdominal wall, then through the muscles where it sometimes resides or proceeded further until the subcutaneous connective tissue was reached. The finding of the sparganum along the coils of the intestines under the serosa suggests that its penetration through the wall of the digestive tract was not perpendicular. Such a behaviour is beneficial to the host as it tends to limit the possibility of carrying whatever infectious organisms are in the digestive tract into the peritoneal cavity.

DEFINITIVE HOSTS

Experiment 9: Subcutaneous transplantation of spargana in cat.—This experiment was designed to determine whether the sparganum can find its way into the intestinal canal and attain maturity or an aberrant form can be produced by this route of infection. The latter is described as irregular branching form and capable of proliferating numerous buds which separate from the parent body and migrate to new locations in the host to grow and repeat the process (Mueller, 1938).

To test the two objects above enumerated a cat was operated November 20, 1942 and two spargana recovered from a frog, kept in saline solution over night in the refrigerator, were transplanted under the skin at about the pubic region. Three days after an enlargement developed at the site of operation. December 5, the enlargement completely disappeared. All this time fecal examination for the eggs of diphyllbothrid tapeworm was negative. February 10, 1943, another transplantation was carried. In this case, 12 spargana were introduced into two sites in the fold of the skin anterior to the inner thigh. The donor of the spargana was a monkey artificially infected. Two days later two red and firm swellings were observed at the seat of transplantation. February 15, 1943, the cat developed excitement and salivation shortly after feeding. Further and subsequent fecal examinations were negative of eggs of *Diphyllbothrium erinacei*. On January 23, 1944, or 405 days after initial transfer, the animal died from starvation. On autopsy 13 spargana were recovered, eleven in the inguinal region and two in the subcutaneous tissue of the abdomen very close to the

site of transplantation. No branching form was noted, neither did they migrate far from the point of introduction. Out of the 14 spargana only one was lost in the operation.

This experiment was repeated on May 8, 1943 using a cat harboring an adult *Diphyllobotrium erinacei*. Four spargana recovered from a frog were employed. August 2, 1943 or 86 days after the operation, the cat died. Autopsy performed, and two spargana recovered in the subcutis not far from the thigh. Examination of the recovered spargana showed no tendency to budding.

The results of the above experiment disclosed the inability of the larval tapeworm to find its way into the intestine when introduced under the skin. Moreover, no branching forms were noted in spite of its long residence in the cat, which covered a period of over a year. In this connection Feng et al. (1938) recorded their failure to produce the branching form as a result of mechanical injury to the sparganum before transplantation. However, one interesting fact disclosed was that a supposed center responsible for regeneration, growth, tissue penetration and development to the adult parasite was tentatively located close behind the base of the groove of the scolex.

Experiment 10: Oral infection of cat and dog with Sparganum erinacei.—September 14, 1941, an adult alley cat was given in gelatin capsule one sparganum recovered from a frog. Two days later fecal examination revealed eggs of *Ancylostoma braziliense* and *Toxocara cati*. From October 1 to 7, 1941 another fecal examination showed the same eggs. However, on October 11 eggs of *Diphyllobotrium erinacei* appeared for the first time 28 days after oral infection, together with those of hookworms and ascarids. December 16, 1941, the cat became negative of tapeworm eggs but positive of both hookworms and ascarids. On autopsy only one female *Toxocara cati* and three female and four male *Ancylostoma braziliense* were collected. The patent period of the tapeworm infection was determined to be 67 days. All told the duration of the infection covered 95 days including the prepatent period of 28 days (Pl. 2, fig. 9).

This was repeated in a female cat. The animal was given 2 spargana in gelatin capsule. The prepatent period was shorter by 18 days than the former, it being 10 days. Incidentally this she-cat was also infected with *Ancylostoma braziliense*. Twenty-nine days later it was killed and on necropsy one *Diphyllobotrium erinacei* and several *Ancylostoma braziliense* were

recovered. The former was preserved in 3 per cent formalin solution and studied morphologically. It was found indistinguishable from *Diphyllbothrium erinacei* described by various authors.

In a laboratory-raised cat the oral infection experiment was further checked. In this case the animal was parasite-free. The prepatent period was 24 days. Eighty-four days after the initial appearance of the eggs of *Diphyllbothrium erinacei* in the feces the cat unfortunately died, due to an unknown intercurrent ailment. Autopsy revealed one *Diphyllbothrium erinacei*.

The cat series was followed with dogs. Accordingly, September 24, 1941, a six-month-old laboratory-raised pup was infected orally with two spargana obtained from a frog. October 11, eggs of the tapeworm were noted for the first time, 17 days after infection. October 22, a segment of tapeworm 86.5 centimeters long by 1.3 centimeters wide passed out spontaneously with the bowel movements. November 27, another segment of 31 centimeters long by 1.2 centimeters wide was again noted with the feces. Microscopic examination of the feces became negative of the eggs of *Diphyllbothrium erinacei*, May 21, 1942, for the first time. To assure that the feces was totally negative of eggs, it was checked daily up to May 26. In all instances no ovum was noted. The day following it was killed and the intestinal tract was found totally free of helminth.

December 13, 1941, another pup was fed orally one sparganum recovered from a bittern but maintained in the laboratory in a mouse from October 20 to December 13, 1941. December 19, fecal examination negative of tapeworm egg but positive of hookworms and ascarids. December 26, the animal died. Autopsy revealed a diphyllbotrid tapeworm and several hookworms and ascarids. Another dog was given one sparganum recovered from rat on December 19, 1941. Previous to the infection, the feces of the dog was determined positive of hookworms and ascarid eggs. January 6, 1942, the dog was observed very weak due to distemper, hence killed and necropsied. One *Diphyllbothrium erinacei* was recovered from the small intestine along with a number of hookworms and ascarids. Simultaneous with this feeding experiment another dog was also infected with one sparganum. On January 11, 1942, or 23 days after infection, the animal died and on autopsy revealed no tapeworm; instead several hookworms were collected.

It is rather unfortunate that only two animals out of the seven employed were able to survive the course of infection. One fortunate coincidence, however, was that one representative of each species remained alive for a complete observation. Out of the three cats used in the first series I was able to determine at least the prepatent period ranging from 10 to 28 days with an average of 20.6 days. In one cat, the duration of the patent period was 67 days but this figure cannot be relied upon as the third cat which died prematurely, the patent period thus far noted exceeded already the 67 days record for the first animal by 17 days. If this cat had lived long enough the patent period may have been extended further.

In the second series where dogs were employed, out of the 4 animals used 3 caught the infection. In the first animal which survived the disease the prepatent period was 18 days and the patent 233 days. The duration of the sojourn of the tapeworm in the gut of the dog was 251 days. Two other animals that became infected as a result of the oral infection died early, even before the feces became positive of the parasitic tapeworm ova, and demonstrated the immature *Diphyllobothrium erinacei* on autopsy.

In this series it was further determined that the spargana of a frog and a bittern were the larvae of *Diphyllobothrium erinacei* as morphological study of the recovered tapeworms from the intestines of the artificially infected cats and dogs answered well the known descriptions of the tapeworm in question (Pl. 3, figs. 13, 14, 15 and 16).

OCCURRENCE OF THE ADULT TAPEWORMS IN CATS AND DOGS

During a decade 2,488 dogs and 152 cats were admitted in the College small animal clinics. Ten dogs and five cats were positively diagnosed as suffering from *Diphyllobothrium erinacei*. The incidence in the dogs and the cats is 0.4 and 3.3 per cent respectively. These data are decidedly lower than those reported by Wharton (1917) and Refuerzo and Garcia (1936) in dogs with an incidence of 5.72 and 4 per cent respectively. The low incidence in this report is attributed in the main to the fact that the dogs and cats treated in the clinics were generally well-taken-care of animals, therefore, less exposed to the second intermediate host harboring the sparganum, while those used by previous workers were largely stray dogs. Again the figure in the cat is markedly higher than in the dog, being

3.3 and 0.4 per cent respectively. This circumstance can be explained by the predilection of the cat to eating frogs besides the freedom it enjoys in the house, as cats are seldom tied and confined unlike the dog.

TREATMENT

A number of cases in the cat and in the dog were treated with arecoline hydrobromide in the doses of two milligrams for every kilogram body weight, given in an empty stomach. A light milk diet the night before the day of deworming seems to facilitate the expulsion of the cestode. In some cases, two doses were given orally at an hour interval. Although the drug gave satisfactory results in the cat, frequently alarming reactions were noted consisting of salivation, vomiting, restlessness, increased breathing and straining leading at times to weakness. In the dog it was by far the best preparation employed for ridding the animal of the tapeworm. In one unusual case, the dog had to be treated monthly for a number of months in order to free the victim entirely of the parasite. In this particular case 24 complete tapeworms were recovered besides many segments as a result of the treatment. Beyond a transient salivation, accelerated respiration and occasional vomiting no other untoward reaction attended the administration of the anthelmintic. Recently nemural came into use. It was tried five times in the cat with apparently no effect even when the dosis was increased to twice the recommended dose of one tablet for each eight pounds of body weight and given repeatedly. Another critical test is being conducted to properly evaluate the efficiency of the two drugs above mentioned against *Diphyllbothrium erinacei*. The preventive measure is simple. Cats and dogs should not be allowed to eat frogs, since these are found harboring the sparganum. To a certain degree snakes and birds which prey on frogs are also dangerous if devoured by cats and dogs. Under no circumstance should frogs be used for animal as well as for human food unless thoroughly cooked.

SUMMARY AND CONCLUSION

The life cycle of *Diphyllbothrium erinacei* has been determined. It was found to conform to the *Diphyllbothriidae* type of development. The eggs became embryonated and the coracidia emerged in the culture as early as seven and as late as ten days. In the cyclop the coracidium developed into a proceroid. The infection of the tadpoles with proceroid appeared

to be in connection with feeding. In the tadpole the procercoid was transformed into a plerocercoid, the typical plerocercoid form being reached in the frog. Thereafter, in the cat and the dog the adult tapeworm was attained through oral infection.

Of the 338 frogs secured from various localities and examined for spargana, forty-one yielded the larval tapeworm or an incidence of 12.1 per cent. The number of spargana in positive frogs ranged from one to as many as twenty-five. Other possible auxillary hosts surveyed resulted to convicting one bittern and two snakes.

In the body of the frogs the distribution density of the spargana appeared to be higher significantly in the hind legs and the abdomen than in the rest of the body.

Oral transfer of the spargana demonstrated that with the exception of the fish all species used caught the infection in varying degree. The mice and the rats both wild and laboratory were the most susceptible, while the fish was completely resistant. Of those that were infected, the chicken showed the least larval parasite. The influence of gravity on the distribution of the spargana in the experimentally infected animals was not marked. Because of the various regions where the spargana were found on autopsy, one can trace the route taken by the sparganum until the final destination in the muscles and subcutaneous tissues of the intermediate hosts.

In the subcutaneous transfer in cats the sparganum failed to reach the intestine nor did it change in form or wandered far from the site of infection. In a wild rat infected orally with frog spargana three normal branching forms were recovered on autopsy.

In the oral transfer of the spargana in cats and dogs, with the exception of one dog, all caught the infection. In cats the prepatent period was on the average of three animals 20.5 days with a range of 10 to 28 days. In dogs it was 18 days. The patent period in a cat was 67 days but this can not be taken as a reliable index as another cat similarly infected but died prematurely, the period exceeded the 67 days record by 17 days. In one dog the patent period was 233 days.

Morphological studies of the recovered cestodes from the experimental animals disclosed the tapeworm to be indistinguishable from those already described for the species.

The incidence of the adult tapeworm in the dog and the cat was found to be 0.4 and 3.3 per cent respectively. Of the two drugs tested against the tapeworm, arecoline hydrobomide appeared to be the drug of choice. As preventive measure, dogs

and cats should not be allowed to eat frogs and other auxillary hosts of the cestode.

REFERENCES

- AFRICA, C. M. Experimental infection of Philippine cyclop with coracidia of *D. mansonii* Cobbold 1882. Phil. Jour. Public Health **1** (1934) 27-31.
- CHANDLER, ASA C. Introduction to parasitology with special reference to the parasites of man. New York, John Willey and Sons, Inc., 1949 756 p.
- FENG, L. C., R. HOEPLI and H. J. CHU. Studies on the sparganum of *Diphyllobothrium erinacei* in regard to immunity and regeneration. Chinese Medical Jour. **54** (1938) 530-546.
- HAN, GAN KOEN. Experimenteel onderzoek over den ontwikkelings-cyclus van *Diphyllobothrium ranarum*. Druk. "Insulinde"-Soekaboemi (1941) 9-102.
- IRA-CONCEPCION, F. A. A new parasite in the Philippines. Bull. San Juan de Dios Hosp. **9** (1935) 277-279.
- IWATA, S. Some experimental and morphological studies on the post-embryonal development of Manson's tapeworm, *Diphyllobothrium erinacei* (Rudolphi). Jap. Jour. Zool. **5** (1933) 209-247.
- IWATA, S. Some experimental studies on the regeneration of the plerocercoid of Manson's tapeworm, *Diphyllobothrium erinacei* (Rudolphi) with special reference to its relationship with *S. proliferum* Ijima. Jap. Jour. Zool. **1** (1934) 139-158.
- JOYEUX, C., E. HOUEMER and J. BAER. Recherches sur la biologie des sparganum et l'etiologie de la sparganose oculaire. Bull. Soc. Path. Exot. **27** (1934) 70-78.
- KOBAYASHI, H. Studies on the development of *D. mansonii*. Jour. Med. Assoc. Formosa **30** (1931) 16-38 and 133-147.
- MUELLER, J. F. The life history of *D. mansonoides* Mueller, 1935 and some considerations with regard to sparganosis in the United States. Am. Jour. Trop. Med. **18** (1938) 41-66.
- MUELLER, J. F. Studies on *Sparganum mansonoides* and *Sparganum proliferum*. Am. Jour. Trop. Med. **18** (1938) 303-328.
- MUELLER, J. F. Sargana in natrix. Science **85** (1937) 519-520.
- OKUMURA, T. An experimental study on the life history of *S. mansonii* Cobbold (A preliminary report). Kitasato Arch. Exp. Med. **3** (1919) 190-197.
- REFUERZO, P. G. and E. Y. GARCIA. Metazoan intestinal parasite of street dogs in Manila and environs. A preliminary report based on two hundred autopsies. Phil. Jour. Public Health **3** (1936) 37-43.
- TUBANGUI, M. A. Pseudophyllidean cestodes occurring in the Philippines. Livro Jubilar Prof. Travassos. **111** (1938) 489-494.
- TUBANGUI, M. A. Warm parasites of the brown rat (*Mus norvegicus*) in the Philippine Islands, with special reference to those forms that may be transmitted to human beings. Philip. Jour. Sci. **46** (1931) 587-591.
- WHARTON, L. D. The intestinal worms of dogs in the Philippine Islands. Jour. Parasit. **4** (1917) 80-82.

ILLUSTRATIONS

[Abbreviations used: es—cirrus sac; gp—common genital pore; ov—ovary; t—testis; up—uterine pore; ut—uterus; v—vitellaria].

PLATE 1

FIG. 1. Freshly passed egg.

2. Seven-day old egg showing the hooks (embryonated).

3. Coracidium drawn from a living specimen.

4-5. Oncospheres from a cyclop showing hooks and flame cells.

6. Proceroid constricting its cercomer.

7. Infective proceroid showing calcareous corpuscles, spines anteriorly and thickened wall.

PLATE 2

FIG. 8. Plerocercoid from a tadpole.

9. Sparganum from a frog (x 2).

10-12. Branched forms from a wild rat artificially infected with frog spargana (x 2).

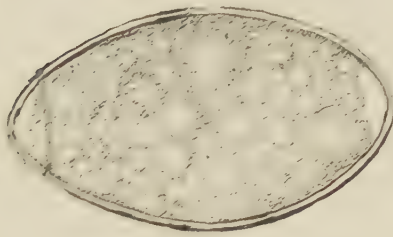
PLATE 3

FIG. 13. Middle proglottid.

14. Terminal proglottids.

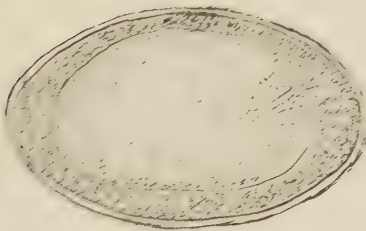
15. Scolex ventral view.

16. Scolex lateral view.



1

0.03 mm



2



3

0.02 mm



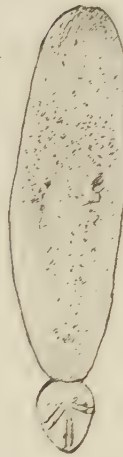
4

0.02 mm



5

0.03 mm



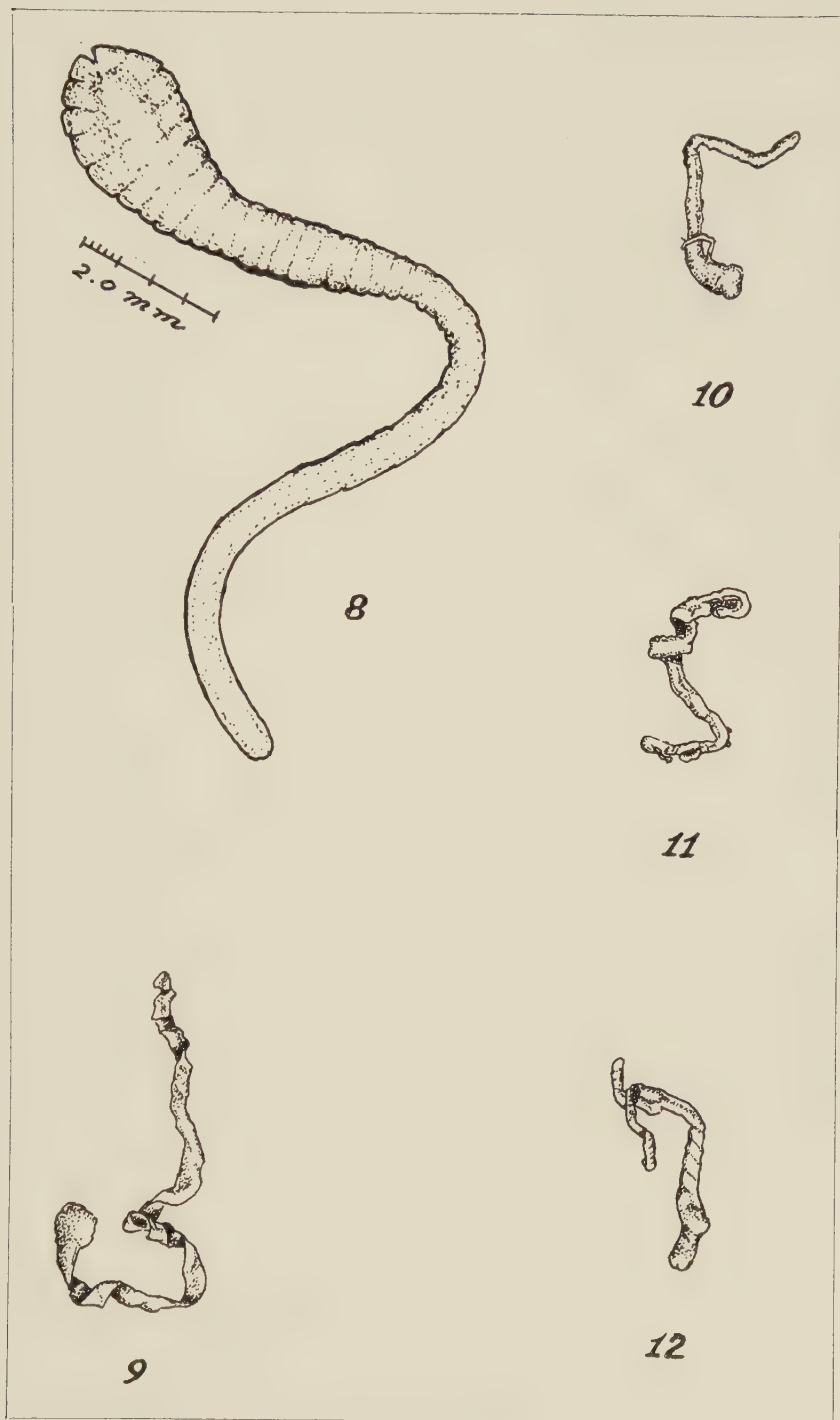
6

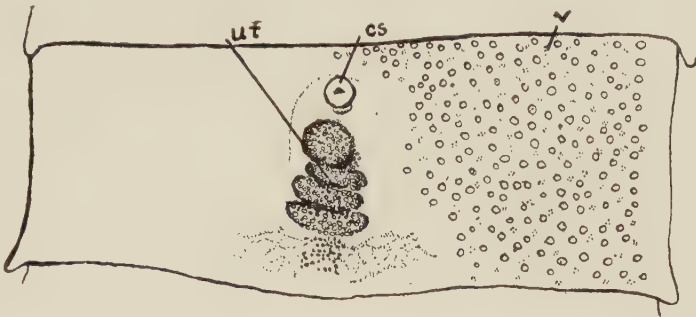
0.04 mm



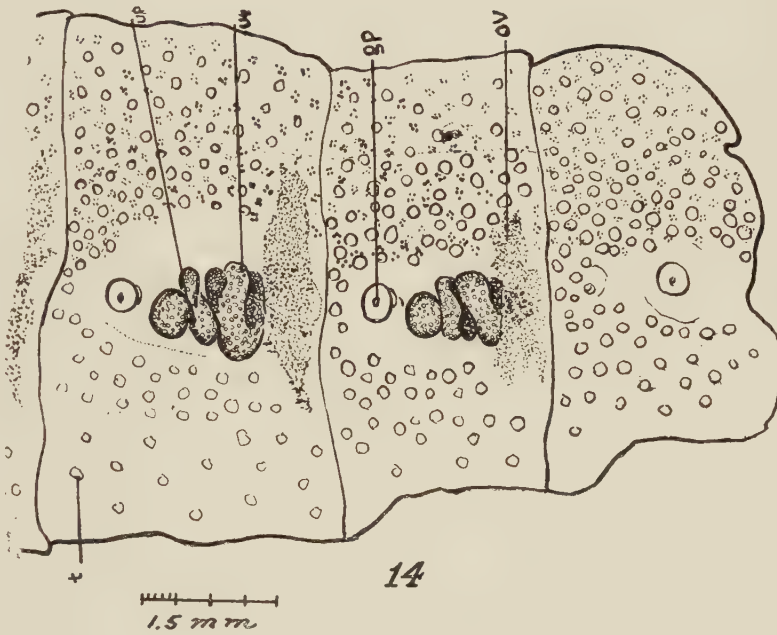
7

0.04 mm





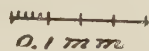
13



14



15



16

NOTES ON CHINESE EGRET, *EGRETTA* *EULOPHOTES* (SWINHOE)

By DEAN AMADON

Of the American Museum of Natural History, New York

The Chinese Egret, *Egretta eulophotes* (Swinhoe) remains a little known bird. The colonies in China were decimated by plume hunters at an early date, though not before a series was collected for the British Museum (Natural History). The colonies in Formosa and Korea are seldom visited by collectors. Wintering migrants are taken infrequently. Perhaps because of their rarity in many collections, specimens of *eulophotes* are often misidentified as *Egretta garzetta*, as the white phase of *Egretta* (*Demigretta*) *sacra*, or even as the much larger *Egretta intermedia*. In breeding dress the tuft of rather long plumes on the nape, among other things, separates *eulophotes* from all these species. In immature or winter dress, the shorter, yellowish (not black) bill and shorter tarsi separate it from *garzetta*; while it can usually be distinguished from *sacra* without too much trouble by its longer tarsi and shorter wings as well as by other minor details (see Meyer and Wiglesworth, *Birds of Celebes*, 2:823-826, pl. 44, Key).

Recently, while examining some Ardeidae in the British Museum (courtesy of the officials of that institution), I noticed three specimens of *eulophotes* from the Philippines as follows: Cebu (March, male), Samar (April 23), and Bohol. Two of these were correctly identified, the third had been called *sacra*. On returning to New York I found another Philippine specimen (Panay, Jan. 20, 1888); this one was misidentified as *garzetta*. Neither of the standard reference works on the birds of the Philippines (McGregor; Delacour and Mayr) so much as mentions the Chinese Egret. La Touche (1931-1934), *Birds of Eastern China*, 2:451 wrote, apparently quite correctly, that it "winters in Celebes and in the Philippines Is.," while Stresemann, *Jour. f. Orn.* 89 (1941) 86, mentions a specimen from Cebu, Philippines. Both La Touche and Stresemann may have based their statements on the specimens in the British Museum.

If *eulophotes* is only a migrant from Formosa, the fact that the four Philippine specimens mentioned above are all from the central group of islands, as well as the absence of records from Luzon, is surprising. Possibly it is a resident in the Philip-

pires, and the same might even be true of Celebes. Meyer and Wigglesworth mentioned an April specimen in breeding plumage from the latter island. Stresemann (*loc. cit.*) evidently overlooked this record, and listed October specimens only.

Another specimen of *eulophotes* in the American Museum of Natural History (June 16, 1904) is from Iriomoto-shima in the southern Loo Choo (Riu Kiu) Islands. Presumably it was a straggler from Formosa. This specimen, taken by Owston's collectors, was labeled "*Ardea garzetta juv.?*," but had been put away with *E. sacra*. *E. eulophotes* is not listed from the Riu Kius in the Japanese Hand-List.

One final correction: in their paper on *Demigretta sacra* (Amer. Mus. Novitates, No. 1144 (1941) 5 Mayr and Amadon wrote "We have only one pure white nestling (Ningpo, China) . . ." This bird is an immature, not a nestling, and it is *eulophotes*, not *sacra*! The present writer was responsible for these errors. It will be recalled that the immature of the white phase of *sacra* is speckled with gray. Probably this is always present.

The following measurements of the wing and tarsus of the specimens of *eulophotes* in the American Museum of Natural History may aid others in identifying this species, which so perfectly bridges the gap between *Egretta* and "*Demigretta*."

	Wing	Tarsus
♂ ad. Korea	270	84
♀ ad.? Riu Kiu Is.....	245	85
Ad. China	245	79
Imm. China	250	88
Ad. Panay, Philippines	267	93

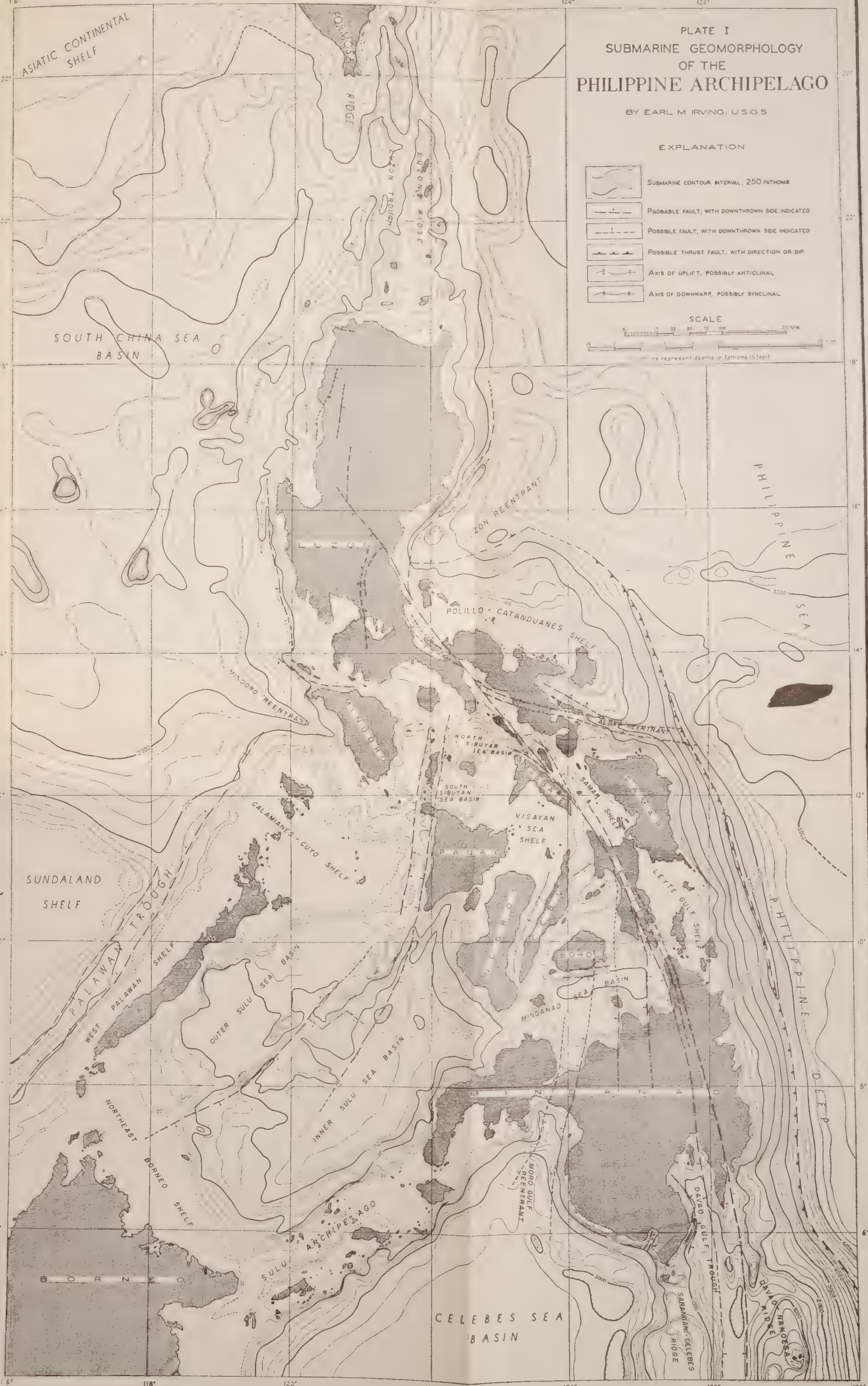
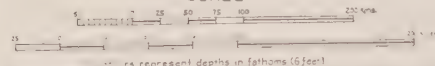
PLATE I SUBMARINE GEOMORPHOLOGY OF THE PHILIPPINE ARCHIPELAGO

BY EARL M. IRVING, USGS

EXPLANATION

- SUBMARINE CONTOUR INTERVAL, 250 FATHOMS
- PROBABLE FAULT, WITH DOWNTROWN SIDE INDICATED
- POSSIBLE FAULT, WITH DOWNTROWN SIDE INDICATED
- POSSIBLE THRUST FAULT, WITH DIRECTION OR DIP
- AXIS OF UPLIFT, POSSIBLY ANTICLINAL
- AXIS OF DOWNWARP, POSSIBLY SYNCLINAL

SCALE



SUBMARINE MORPHOLOGY OF THE PHILIPPINE ARCHIPELAGO AND ITS GEOLOGICAL SIGNIFICANCE

By EARL M. IRVING¹

Geologist, U. S. Geological Survey

TWO PLATES AND ONE TEXT FIGURE

INTRODUCTION

For nearly fifty years the U. S. Coast and Geodetic Survey has been sounding and charting Philippine seaways. These comprise almost two-thirds of the Republic's territory as delimited by international treaty. It is with infinite regret that this very capable organization has brought to a close its great pioneering work.

Geologists, in contrast to geodetic engineers, must confine their work mainly to land areas. The object of the present paper is to utilize the vast amount of sounding information resulting from the Coast and Geodetic Survey's work in order to learn more of the nature of submarine topography and to evaluate its significance with respect to regional geology.

Bathymetric maps of the archipelago have been prepared on various occasions, but owing to excessive generalization, or to insufficient sounding data to allow employment of smaller isobathic contour intervals, or to defects of technique, few portray submarine features well enough to admit of much geological interpretation. On the other hand it is well known that without adequate sounding control one may fall into the snare of interpreting more intelligence into such a map than is justified by the available data. It is hoped that this has been averted by making use of the vast number of soundings existing on the original work sheets, which are deposited in the Geodetic Survey Office, and by limiting description and discussion mainly to larger features. Interpretation of smaller features requires not only high concentration of soundings but also intimate familiarity with the geology of particular areas.

It is confidently believed that careful examination of submarine features will yield not only valuable information, but to the imaginative, a wealth of stimulating ideas whose further study may result with a better understanding of Philippine regional geology.

¹The author acknowledges with deep appreciation the constructive suggestions of Dr. Mateo Tupas who critically reviewed the manuscript.

CRITERIA FOR THE RECOGNITION OF SUBMARINE FORMS

Because soundings in open seas are spaced at intervals roughly of one to ten miles, detailed forms cannot be discerned in these areas. This spacing may permit, however, some concept of the broader submarine features where they are of large scale. Additional soundings in such areas doubtless would reveal numerous and interesting details.

In areas where there is pronounced shoaling of waters such that shipping might be endangered, near coastlines, and especially in harbor areas, soundings are much more closely spaced, often at intervals of as close as 100 yards. In these areas often 2 to 10 times the number of soundings exist on the field work sheets than are recorded on published maps. Considerable detail of form may be distinguished in such areas, and standard physiographic criteria for interpretation of geologic forms are applicable.

In conjunction with physiographic criteria there are, in addition, several lines of geologic evidence that may be utilized to assist in deciphering the various submarine forms. The most direct of these are the observations of regional geology on adjoining land. If, for instance, a strong fault of known attributes on land passes beneath the sea, and we find a strong escarpment beneath the sea along the direct prolongation of the fault, this would be substantial evidence that the fault has caused displacement of the sea floor. Further, if volcanism has been controlled by the fault on land and we find a row of volcanic islands along the projected submarine extension of the fault, this would be corroborative evidence for the existence of the fault beneath the sea. If it is also known that movements on the fault cause a concentration of earthquake epicenters along its trace, beneath the sea as well as on land, we have clear proof for its existence beneath the sea. Per contra, of course, faults clearly distinguishable beneath the sea, by projection landward, may reveal the location of faults on land that heretofore have escaped detection.

Faults, old and new, active and inactive, show a wide variety of outward manifestations. Nature is rarely so generous as to provide a large number of converging criteria for their recognition. Moreover, whereas erosion is the modifying agent of physiographic forms on land, sedimentation tends to mask physiographic forms beneath the seas. Thus, without analyzing the gamut of geological criteria for recognition of all external forms, one must, in general, employ every

possible line of converging evidence at his command for the interpretation of forms. But above all, he must at the same time retain a high level of critical sensitivity lest his imagination carry him into the tenuous realm of the hypothetical.

BROAD RELATIONS OF PHILIPPINE SUBMARINE TOPOGRAPHY

The area of the Philippine archipelago is roughly of triangular shape; in north-south direction it subtends 17-1/2 degrees of latitude; in east to west direction the southern base of the triangle subtends 9-1/2 degrees of longitude. The northern point of the triangle lies slightly east of the southern end of Formosa. The east side is bounded by the Pacific Ocean, the west side by the China Sea, and the south side by the Celebes Sea. This triangular area is considerably removed from the Asiatic Continent and lies between Formosa on the north and Borneo and Celebes Islands on the south.

This geometric but preeminently artificial description, however, conveys little or nothing of the physical relationships of the archipelago to the adjoining island arcs, and to the seas and oceans between them. The relations are best perceived from a regional bathymetric map that shows the configuration of the adjoining sea floor. In Fig. 1, we see in fact that the Philippine archipelago is situated in an extremely complicated portion of the earth's crust, the more eastern islands of which emerge along the summit of a broad principal ridge of sigmoidal pattern that detaches from the southeastern side of the Formosa ridge, passes through the Philippines, splits in southeastern Mindanao, one branch dying out on the sea floor between Halmahera and Celebes Islands, and the other connecting with the northern arm of Celebes Island.

Bifurcating from the principal Philippine ridge are two subordinate ridges, i. e. the Palawan and the Sulu archipelago ridges. These diverge southwestward from the principal ridge and as isthmian links connect with the great island of Borneo.

The principal ridge and its two diverging subordinates, moreover, mutually delineate the major bodies of water. The main ridge in its northern part separates the China Sea from the Pacific Ocean proper. The southern continuation or submerged portion of this ridge, and the two diverging subordinate ridges block out three large bodies of water which from east to west are: the Celebes Sea, the Sulu Sea, and the southeastern part of the China Sea. Each of the containing sea basins reaches maximum depths locally of 3,000 fathoms, almost but not quite, the depth of the Pacific Ocean itself.

The Philippine deep, the greatest of any ocean, lies immediately east of the main sigmoidal ridge, and extends from the middle of the Philippines southward to and beyond the southern end of Mindanao.

These then, are the principal elements of the foundation of the Philippine archipelago. But in detail, individual elements of relief possess a remarkable variety of superimposed minor ridges, escarpments, and shelves, and the relief elements are often separated by elements of negative relief such as troughs and valleys, and internal basins. The description and the correlation of these features with surface features are the objects of the present paper; they will be described as consecutively as possible in order of decreasing depth.

THE PACIFIC COASTAL REGION

The Philippine deep.—The Philippine deep (see Plate I) lies in the open sea of the Pacific basin immediately east of the Samar and Mindanao islands. Although soundings are few and widely spaced in southerly direction, the deep bends eastward and extends for some distance south of the latter island. Of 10 cable soundings recorded in the axis of the depression exceeding 30,000 feet, the deepest is 5,704 fathoms, or 34,224 feet. The deepest portions of the trench pass 10 to 15 thousand feet below the average level of the Pacific Ocean floor and are found in several small closed basins along its length.

The deep is sharpest and narrowest in its northern part opposite Samar and northern Mindanao islands. Both northward and southward it tends to shoal, and finally becomes indistinguishable from the ocean floor. The side slopes appear to be smooth, similar, and apparently symmetrical to a vertical plane even though the landward side rises to much greater heights than the oceanward side. Although the submarine contours are closely spaced within the trough, profiles show that the slopes rarely exceed 11 degrees.

The origin of the Philippine deep undoubtedly has great significance in the tectonics of the archipelago. According to Hess (1948), the intra-Pacific island arcs and deeps, and some of the circum-Pacific arcs and deeps are believed to have come into existence near the end of the Mesozoic era. Umbgrove (1947) shows that some of the East Indies deeps came into existence in the late Tertiary period. From seismologic evidence we know that they are tectonically very active now. The origin and significance of the deeps will be discussed on a later page.



FIG. 1. Regional bathymetric map of a part of the Southwest Pacific showing the relation of the Philippine archipelago to the Asiatic continent, adjoining islands and archipelagos, and to the seas. Depths in meters. (Adapted and extended from van Riel).

Pacific Ocean floor.—From a hypsographic curve of the earth's surface it is well to recall that there are two frequency maxima, one at 100 meters above sea level corresponding to continental areas, and another at a depth of 4,700 meters (2,570 fathoms) which corresponds to the ocean basins. From geodetic, seismologic, and geologic considerations, these are commonly considered to represent surfaces of equilibrium in position of large segments of the earth's crust. The continental areas of high elevation and position are underlain by rocks of lower specific gravity (etwa 2.65) consisting of so-called "sial," and the deep oceanic areas are underlain by rocks of greater specific gravity (etwa 3.0) consisting of "sima." Any appreciable deviation of the earth's surface above or below these surfaces of hypsographic maximum and minimum elevation, as the case may be, requires special explanation.

Kossina (1933) has shown that there are fundamental differences for instance between the Atlantic and Pacific Ocean basins. The following table shows the distribution of isobathic areas in the Atlantic and north Pacific basins.

Depth	North Atlantic	South Atlantic	North Pacific
Kms.	Per cent	Per cent	Per cent
0.0-0.2.....	7.06	4.29	1.55
0.2-1.0.....	4.89	3.22	1.13
1.0-2.0.....	4.89	2.57	1.13
2.0-3.0.....	8.16	6.87	2.68
3.0-4.0.....	18.21	19.74	12.43
4.0-5.0.....	31.26	34.76	29.94
5.0-6.0.....	23.91	28.11	46.90
6.0.....	1.62	0.43	4.24
Total area Km.....	36.8	46.6	70.8
Ave. depth (meters).....	3,788	4,036	4,753

From this data it is seen that the average depth of the north Pacific basin is fully 1,000 meters greater than that of the Atlantic Ocean. It is this fact, together with data from earthquake wave velocities and the existence of essentially isostatic equilibrium, that the sima of the Atlantic basin is believed to be overlain by a thin layer of sialic material, thus accounting for its shallower depth.

If one examines Hydrographic Office Chart No. 5485 (1946), U. S. Navy, it is noted that the westernmost portion of the Pacific basin, that part lying west of the "andesite" line and commonly known as the Philippine Sea, is considerably shallower than the north Pacific basin proper. A large part of the westernmost Pacific varies between 2,000 and 3,000 fathoms

in depth. Only in the central part of the Philippine Sea basin do substantial areas pass below 3,000 fathoms. It thus appears that this portion of the Pacific basin possesses a depth perhaps somewhat intermediate between the Atlantic and the north Pacific basins. From gravity determinations (Vening Meinesz) and earthquake wave velocities, it is believed by some that the westernmost portion of the Pacific basin also possesses a thin layer of sial over it.

Immediately adjacent to the Philippine deep, the Philippine Sea floor undulates broadly from 3,000 to 3,500 fathoms. Easterly from the prominent reentrant north of Polillo Island, the floor of the Philippine Sea rises quite sharply along an east-west zone. North of this rise the sea floor varies between 2,500 and 3,000 fathoms in depth. It is not known whether the coincidence in position of this rise with the eastward projection of the Luzon reentrant has structural significance or not; the coincidence in latitudinal position of the two features seems to suggest that there may be some structural relationship.

Eastern escarpment of the Philippine archipelago.—The eastern margin of the main Philippine ridge possesses several pronounced features: a sharp rise from the monotonous undulating surface of the ocean floor; a sharp, trench-like reentrant at the San Bernardino Strait; and a broad angular reentrant north of Polillo Island which sets the northern coast of Luzon quite apart from the remaining portion of the Pacific coast. The two reentrants produce a triple-scalloped configuration in the escarpment.

The Albay reentrant heads into the San Bernardino Strait from the Philippine deep and is often represented on maps as a trough simulating a submarine canyon. This feature is believed not to be a submarine canyon, however, for it finds expression in direct projection from the elongate, high, and steep-sloped island of Rapu-Rapu, and carries down to a depth of more than 2,000 fathoms. Moreover, its length is only about three times its width and no other similar feature exists along the entire Pacific coast, embracing a distance of more than a thousand miles. Because the feature projects in a nearly straight line with a zone of strong rifting on the Cagraray Peninsula, with Mayon Volcano, and a pronounced graben structure in the Ragay Gulf, it is believed this reentrant is of structural origin and may in some way be related to a zone of adjustment between the great Philippine rift zone and the

Philippine deep structure. In fact the rather regular periodic eruption of Mayon Volcano may reflect the operation of these forces.

The Luzon reentrant north of the Polillo-Catanduanes shelf is of particular interest because of the very sharp interruption it causes in the trace of the north Pacific coast of Luzon Island. The northern slope of the Polillo-Catanduanes shelf is not particularly steep but near its base, north of Polillo Island, is an elongate depression, and farther to the east, the Pacific floor itself passes into a closed basin of a depth of 3,000 fathoms, some 300 to 400 fathoms below the surrounding floor. The Luzon coast side of the reentrant, on the other hand, shows a very sharp crease which lies behind a pronounced ridge between the escarpment and the ocean floor. This crease, hugging the coastline very closely, is nearly 100 miles long. The reentrant area, it must be concluded, is probably complicated by marginal faults, although additional soundings are needed in order to determine their nature and position accurately. The relative age and relation of these structures to the so-called master fault or Philippine rift zone will be a problem for future study. Not less noteworthy in this northern portion, as mentioned before, is the shallower depth of the Pacific Ocean floor from that opposite the southern Philippines.

DEEP SEA BASINS

South and west of the Philippines are three deep sea basins: the Celebes Sea basin, the Sulu Sea basin, and the China Sea basin. These basins are exceptionally large and constitute major elements within the island framework.

The Celebes Sea basin.—The Celebes Sea basin is of irregular elliptical shape, 400 miles wide by 500 miles long, and is bordered by the island of Mindanao, the Mindanao-Celebes ridge, the northern arm of Celebes Island, the northeast coast of Borneo, and the Sulu archipelago ridge. From each of these containing land areas, the sea bottom descends sharply to the floor of the basin, resulting that the floor comprises perhaps as much as 75 to 80 per cent of the surface area of the sea itself. The floor of the basin possesses extraordinary low relief and varies in average depth from 2,200 to 2,700 fathoms. In general it slopes eastward, and the greatest depths are found in the northeastern corner where several small closed basins reach maximum depths from 3,100 to 3,400. Because the floor of the basin is devoid of topographic and structural features,

and because its depth at the eastern or outer edge is so great, similar to that of the Pacific Ocean, one might reasonably argue that the basin proper is an original and primary feature of the regional structure, and has maintained structural individuality despite the tectonic vicissitudes of adjoining land areas. That it is somewhat shallower than oceanic areas may be explained by sedimentary filling from adjoining land areas during its possible long life.

Of special interest is the location of its deepest portion, off the south Mindanao coast and next to the Mindanao-Celebes ridge.

The Sulu Sea basin.—The Sulu Sea basin is a northeasterly-trending elliptical body of water, 200 miles wide by 350 miles long, enclosed by the Visayan islands, the Zamboanga Peninsula of Mindanao, the Sulu archipelago ridge, northeast Borneo, and the Palawan-Calamianes ridge. The basin is separated from the Celebes Sea basin and the China Sea basin by two slender ridges, the Sulu archipelago ridge and the Palawan-Calamianes ridge respectively.

Departing from Dao Peninsula of southwestern Panay, and forming almost a straight line connecting Cagayan, Cavili, Meander reef, and Cagayan Sulu Islands, the Sulu Sea is divided longitudinally into two parts. The floor area northwest of this linear zone is quite distinct from that to the southwest.

The floor northwest of the line possesses three pronounced surfaces of distinct level below the sea: one at a depth of about 60 meters corresponding to the Calamian-Cuyo and the north Borneo shelf areas; another at a depth of 820 fathoms represented by the pronounced bench extending between Cagayan Island and northern Palawan Island; and another at 1,120 fathoms corresponding to the central deeper portion. The cause for the existence of such broad areas of differing levels is not readily apparent, although some may wish to ascribe them to faulting.

Southeast of the same line, the sea floor passes sharply to much greater depths. Immediately southeast of the line the southeastern part of the basin possesses several northwesterly trending ridges and valleys. The central area varies in depth from 2,100 to 2,400 fathoms. Maximum recorded depths, similar in location to those of the Celebes Sea basin, are in the northeast corner of the basin as two closed areas whose maximum depths are respectively 2,847 and 3,049 fathoms.

Because of the sharp difference in average depths of the two parts of the Sulu Sea basin, the Sulu Sea is therefore divided into the Outer Sulu Sea, the shallower western part, and the Inner Sulu Sea, the deeper eastern part.

The line of demarcation separating the two areas invites attention. Dao Peninsula, southwest Panay, is broadly a plunging anticlinal structure composed of upper Tertiary sediments with a pre-Tertiary crystalline core. It is expressed beneath the sea as a ridge that plunges in a straight southwesterly course to a depth of 2,200 fathoms. West of this ridge is a sharp trough-like reentrant whose northern continuation passes into a longitudinal depression off the west coast of Panay. It is not readily apparent whether the plunging nose and the parallel reentrant are fold structures or whether they are the product of faulting. One might surmise that they are a combination of both.

Extending southwesterly from the reentrant are a series of southwesterly trending elevated tracts upon which reefs of varying depth and size are constructed. Exposed portions of the masses consist entirely of reef limestones although Cagayan Sulu Island, the southernmost of the lineal chain, is composed almost entirely of volcanic rocks. Owing to the considerable depth of the surrounding basin floor, it may well be supposed that the reefs rest upon mounds of older volcanic material.

Evidently at a comparatively recent date, strong faulting has modified the conformation of the floor. West of the Cagayan and Arena-Cavili Island reefs, the Sulu basin floor of 600 to 800 fathoms below sea level. East of this linear series of islands the Inner Sulu basin floor from 2,000 to 2,300 fathoms. The sharp disparity of levels of the floor on either side, and the sharp southeast profile of the island masses is strongly suggestive of faulting of large magnitude.

Tubataha reef in the central part of the Sulu Sea, on the other hand, is offset in a westerly direction from the foregoing. Between it and Meander reef, and continuing southwesterly in less pronounced manner toward San Miguel Island, the floor of the Sulu Sea basin again shows a remarkably linear, sharply breaking profile between the outer and inner basins. The floor west of this line possesses very low relief and varies in depth from 1,060 to 1,160 fathoms. The floor east of the line varies in depth from 1,700 to 2,200 fathoms, a difference in depth of 640 to 1,040 fathoms. East of both Tubataha and Meander reefs, moreover, is a linear trough-shaped depression,

not unlike a sag-basin. It is quite probable, therefore, that a strong fault passes along the eastern bases of the islands, which is probably not the same fault as that southeast of the Cagayan and Arena-Cavili islands.

Considering the northwesterly trend of the masses supporting these islands, and if it is granted that the bases of the islands are volcanic, as seems probable, it may be presumed that still older faults probably controlled the position of the volcanic vents. Thus the various structures may have developed over a considerable period of time and from the nature of the present fault structures, the line of demarcation that divides the Sulu Sea basin into two parts is a zone of strong rifting, which will be termed the Sulu Sea rift zone.

Elsewhere about the margin of the basin, very sharp shouldered and steep profiles are noted, but not enough evidence is available to ascertain their origin. Of particular interest are the spectacular profiles south of Negros Island and along the Zamboanga Peninsula coast, the linear escarpment south of the Calamianes-Cuyo shelf, and the broad rectangular reentrant heading into Puerto Princesa. Some of these may have been affected or controlled by faulting.

The South China Sea.—The South China Sea is an immense body of water 600 miles wide by 1,400 miles long, lying between the Philippines and Borneo, and the Asiatic continent. Between Formosa and China it is shallow where it shoals over the continental shelf into the shallow East China Sea; southward it passes into the shallow Java Sea. A large area in the central part of the South China Sea basin has a depth varying between 2,000 and 2,200 fathoms. Again the floor slopes northeastward and the deepest part is along its easternmost edge, adjacent to the Zambales and Ilocos coasts of Luzon.

In general, a line drawn between southern Palawan and southernmost French Indo-China separates the deeper northern part from the shallow southern part of the South China Sea. Large areas of the southern part of the South China Sea are not much deeper than 100 fathoms. This shallow area including the Malaya Peninsula, Sumatra, the Java Sea, and Borneo, from our understanding of Mesozoic and Tertiary regional geologic history, is considered to represent the former subcontinental area of Sundaland which during the Tertiary was largely dry land and contributed sediments into shallow basins around it and within it. In late Tertiary and Pleistocene time large

areas were submerged and the region developed its present insular pattern.

From the north coast of Borneo this submerged continental mass extends northward into the area west of Palawan. Over great areas coral reefs have built up from the platform giving rise to the Spratley, Namyt, York, and other island groups, and great numbers of submerged reefs that make it an area exceedingly dangerous for shipping.

Immediately west of Palawan Island is a sharp, linear, trough-like depression in this surface which will be described under appropriate title. This depression has outlet to the deeper China Sea northwest of Palawan.

West of Mindanao Island, the China Sea extends southeastward as a sharp reentrant between Mindoro and the Calamianes-Cuyo shelf. The headward part of the reentrant disperses into an irregular passage that possesses clump-like islands, probably volcanic and coralline, with closed depressions reaching maximum depths of more than 600 fathoms, between them. The area next to the west Mindoro coast is 300 to 400 fathoms deep, and the shallowest part of the passage entering into the area of the Visayan islands is at a point well south of Mindoro Island.

A somewhat smaller reentrant extends from south of Lubang Island into the Verde Island passage north of Mindoro Island. Considering the sharp profile off the southern margin of Lubang Island, the presence of a closed basin north of Mindoro Island along the eastward projection of the reentrant, and the existence of numerous epicenters of sharp earthquakes in this reentrant, it is reasonable to postulate a zone of rifting and faulting in this area. The west-northwesterly trend of this zone is somewhat divergent from the normal trends of known rifting in the archipelago.

The Zambales coast of Luzon is well known for occasional sharp earthquakes, many of which are sensible in Manila. Examining the submarine profile off the coast, one notes that it is a precipitous slope, and possesses a remarkable rectilinear course. Moreover in its northern part, a narrow deep crease in the ocean bottom lies between the Zambales coast and a prominent ridge to the west. The evidence is fairly clear that the eastern margin of the China Sea basin and the Zambales coastline is determined by a north-south zone of rifting. The zone of rifting evidently dies out northward and the throw may be taken up on other, more easterly located, zones following the Ilocos coast of Luzon.

The northeastern corner of the South China Sea basin is determined by the overlapping of two opposing ridge structures, the southerly plunging Formosa ridge and the northerly projecting Luzon ridge. Between the two ridges lies a submarine trough. A cross-axial pass across the Luzon ridge of a depth of 1,473 fathoms is the threshold level that determines the character and quality of the water that passes from the Pacific Ocean into the South China Sea, and in turn, because the Pacific coast of the Philippines is bounded by shallow submarine shelves, the nature of the waters within the archipelago. A great number of earthquakes emanate from this structurally complicated region, and some of them, certainly, must be attributed to the adjustments between the opposing ridges, the trough between them, and the Pacific basin to the east.

Several localized shoals are located within the South China Sea basin and these are probably of volcanic origin.

INTERMONTANE TROUGHS AND SUBMARINE RIDGES

Although objections may be raised to the non-exclusive quality of the definition, the term "intermontane trough" refers to those very deep, sometimes quite flat-bottomed, depressions that exist between submarine ridges. They are to be distinguished from the comparatively shallow troughs at higher levels which will be described shortly. Intermontane troughs possess depths comparable to those of deep sea basins. The ridges on either side possess quite regular pattern. If the water were removed from the troughs, the ridges in relation to the troughs and the adjoining sea floor indeed would comprise ranges from 12,000 to 20,000 feet high.

The best development of intermontane troughs between submarine ridges are those at the two extremes of the archipelago, north of Luzon and south of Mindanao.

North Luzon ridge and trough.—Although the north coast of Luzon trends in an east-west direction and the dominating north-south trend of the northern part of the island seems to be truncated, below sea level the island projects more than 250 miles northward as a tapering irregular submarine ridge which ultimately connects with the base of the Formosan ridge structure. In the Babuyan Island area at a depth of 300 to 600 fathoms the ridge is almost as broad as Luzon Island itself. The Babuyan Islands are mainly volcanic and constitute superposed cones upon the ridge. In the northern Babuyan Islands the water deepens to more than 800 fathoms where Balintang Chan-

nel separates these from the more northerly Batanes Islands, also volcanic. At latitude 22.4° the Luzon ridge proper seems to terminate.

Between the Luzon ridge and the short plunging ridge extending southward from Formosa, lies a broad elliptical closed depression that reaches a maximum depth of 2,800 fathoms. This depression continues southward as an irregular winding trough between elevated submarine tracts and the submerged Luzon ridge.

Davao-Nanoesa and Sarangani-Celebes ridges, and the Davao Gulf intermontane trough.—From southeastern Mindanao two well-defined ridges carry southward for considerable distance. The easternmost ridge extends southward from Davao Peninsula, through Palmas Island, to and beyond the Nanoesa Islands, R.U.S.I. Although Palmas is probably volcanic, the basement rocks of Nanoesa Islands (Roothaan, H. Ph., 1925) are composed of siliceous schists which are intruded by basic intrusives including serpentines, gabbro, and diorite, thus demonstrating that the ridge mass is composed mainly of basement types. Another even more pronounced ridge extends south from Sarangani peninsula and connects with the northern arm of the Celebes Island. Much of the northern arm of Celebes Island is volcanic and it is presumed that the numerous small islands projecting upward from the submerged ridge are probably also volcanic.

Between these two ridges is a broad intermontane trough between 1,800 and 2,000 fathoms deep. The trough lies beneath Davao Gulf, and northward it finds expression as the great linear depression along the Agusan River valley of Mindanao. Much of the Davao Peninsula is composed of basement rocks. The west coast of Sarangani Peninsula is composed of folded Tertiary volcanics and sediments, the exposed edges of which against a steeply descending submarine slope requires explanation. Considering the sharp reentrant nature and the gentle slope of the sea floor, which itself is bounded by steep slopes on both sides, there is some basis for classifying the feature as a graben. Numerous earthquake epicenters are found in this trough.

The prominent ridge upon which the Sulu archipelago is formed, and the Palawan ridge, might well be considered as submarine ridges whose summits are exposed, but because these ridges are different in several respects from the aforementioned they are treated separately.

TROUGHS OF INTERMEDIATE LEVEL

Intermediate in depth between the intermontane troughs just outlined and the quite shallow linear depressions that pass between islands and form straits, are the so-called troughs of intermediate level. The intermediate level troughs of which there are two, the Palawan and the Antique troughs, are of special interest because of their probable geologic significance.

The Palawan trough.—From a point opposite northern Palawan the Palawan trough lies 40 to 60 miles west of Palawan Island and extends for over 400 miles southwesterly toward the north coast of Borneo. The trench-like depression possesses a remarkably uniform width of 40 to 50 miles, and its trend is exactly parallel to Palawan Island. The northern end of the depression where it communicates with the deeper South China Sea basin is 750 to 850 fathoms deep. In southwesterly direction it becomes deeper and west of Balabac Island it reaches a maximum recorded depth of 1,580 fathoms. The trench then shoals gradually to the level of the Sundaland shelf.

There are a number of abnormal geological features about this trench. In early Tertiary time at least, the highland of Sundaland was presumably supplying sediments into the Philippine area. Certainly the siliceous sediments (? Cretaceous) of northern Palawan and the Calamian group as well as the siliceous Oligocene to lower Miocene sandstones of southern Palawan and Balabac islands originated from Sundaland because in the Philippines we know of no adequate sources for clastic sediments of this composition. If this is so, as it certainly appears, the trough could not have existed during these times, otherwise the sediments would have been deposited in it and little or nothing could have passed across the trough. It might be argued on the other hand that the trough is a drainage channel that developed at some later date. This possibility is quickly eliminated by its rectilinear pattern without corresponding tributaries, and especially because the trench possesses a landward gradient, i.e. an inclination opposite from which the drainage should normally have developed. The trench in fact possesses all the features of a graben, and it is here considered as such. The faulting that caused its development is younger than the Sundaland-derived sediments. It may well be Miocene or Pliocene. Few epicenters are now recorded in this area.

The Antique trough.—The second trough of intermediate level lies between the Calamian-Cuyo shelf and the west coast of Panay Island. The rectilinear north-south trending west coast

of Panay has led several writers to presume that the coastline may be structurally controlled. Recent geological data and present sounding information now appear to establish this as a fact.

Geologic mapping of the Sibalom-Valderama area by L. Santos-Yñigo and P. Capistrano shows that the regional geologic structure consists of tightly folded Miocene volcanics and sediments which are extensively thrust-faulted, causing sandwiching of pre-Tertiary basement rocks with the overlying Tertiary sediments. Fold axes, faults, and outcrops of formations trend in north-easterly direction. The coastline, on the other hand, trends in north-south direction, that is, its trace diverges approximately 35 degrees from the trend of geologic structures on the adjoining land. Moreover, we find offshore from the coast, a narrow trough that passes to maximum depths of 750 fathoms, and these are found in a closed basin west of Dao Peninsula. Thus the coastline and the trench which are parallel to each other, are notably divergent from the structure of the rocks inland from the coast.

From the geologic history recorded in the sediments of the Iloilo basin, (Corby, 1940), we find in fact that the area west of Panay probably supplied much of the sediments in the basin. The sediments along the western margin of the basin, i.e. along the eastern base of the Antique range, are much coarser grained and the stratigraphic section is several times thicker than the section of equivalent age along the eastern margin of the Iloilo basin. Santos-Yñigo has shown that principal folding and thrusting in the Antique range probably occurred during the time interval represented by the Iday conglomerate in the basin, i.e., in uppermost Miocene or early Pliocene time. Judging from these facts, graben faulting, resulting with the development of the offshore trench, probably occurred in Pliocene or Pleistocene time and as an aftermath of compression. The northern extension of the marginal faults along the trench give rise to a remarkable horst structure comprising the Buruanga Peninsula of Panay and Tablas islands which will be discussed more fully under subsequent heading.

HIGH LEVEL INTERNAL BASINS

Within the area of the principal sigmoidal ridge comprising Luzon, the central Visayan, and Mindanao islands are several pronounced basins of more or less equant to irregular form. These depressions lie within the ridge itself and therefore

contrast greatly in magnitude and in geological environment with the deep-sea basins already described. Many are complicated on one or more sides by faulting, and probably duplicate in this and other respects the basins of sedimentation that existed at various times elsewhere within the archipelago during the Tertiary period. A careful study of sediments and sedimentation in such existing basins would probably be immensely valuable for a better understanding of Tertiary sediments, stratigraphy, and structure.

The Mindanao Sea basin.—The Mindanao Sea basin lies between Mindanao and Bohol islands and is elongate in an east-west direction, transverse to the trend of the major ridge structure. It is bounded on the east by the shallow Leyte Gulf shelf and on the west by a pass (threshold level, 262 fathoms) between northern Zamboanga Province and Negros Island.

Upon studying a map of northern Mindanao one is immediately impressed by the dentate pattern of the northern coastline. Beginning with Surigao Peninsula, the coastline intermittently and systematically shifts in southerly direction as one proceeds southwestward, until reaching the Oroquieta-Dipolog promontory of northernmost Zamboanga Peninsula, west of Iligan Bay. The dentate pattern, aside from the interruption occasioned by volcanic Camiguin Island, moreover, is repeated in the submarine offshore configuration. The western margin of each promontory possesses excessively steep profiles and the eastern sides are comparatively gentle. Northward, both promontories and intervening bays descend to a floor of common level of about 800 to 850 fathoms, which in turn deepens gradually to 1,050 fathoms along an east-west axis just south of Bohol Island. Thence the floor rises along a steep front to the southern coast of Bohol.

The dentate pattern of the coastline might suggest strong strike-slip movement on several more or less equi-spaced faults. This hypothesis cannot be reasonably excepted, however, because the smallest strike slip component to develop a single promontory would be 15 miles and for the largest, 65 miles. This is excessive.

The solution to the pattern seems best to be determined along the west coast of the Surigao Peninsula, and from this the other promontories may have similarly developed. From regional studies, the so-called Philippine master fault zone is known to pass along the central axis of Leyte, thence along the

Surigao Peninsula, and down the east side of the Agusan River valley. From geologic sections across the Surigao Peninsula at least two major north-south faults cause the development of Lake Mainit in a graben structure. The westernmost of these and a parallel fault along the western coast result with a horst forming the western range of the peninsula, and to the north the horst comprising Panaon Island, southern Leyte. West of the coastal fault the area is depressed and in it we find Butuan Bay. The so-called master fault is thus a complex zone of faulting, and as will be noted later, should be denoted as a "rift zone" in order better to convey its geologic attributes.

The Diuata point promontory west of Butuan Bay, and the succeeding Gingoog Bay, result from a fault along the western side of the promontory. This fault is well displayed on the sea floor. The fault in this case is of scissor type. In the Gingoog Bay area the western side of the fault is downthrown; in the Sogod Bay area of southern Leyte, the eastern side is depressed. The axis of rotation lies in the central part of the Mindanao Sea basin.

The evidence for a fault between the Bagaon point promontory and the succeeding Macajalar Bay near Cagayan consists principally in the sharp off-shore profile and the construction of Hibok-Hibok Volcano and Caminguin Island over it.

Iligan Bay, occupying the southwesternmost of these offsets, is similar in form to the preceding, and hypothetical faults are placed along its margins. Present evidence for a fault along the eastern side, in addition to step offshore profiles, consists principally in the fact that the rocks along the west coast of Iligan Bay are Upper Tertiary while those inland are of basement types, indicating the existence of a tectonic high there. Moreover, along its southern projection we find Lake Lanao basin which is probably a part of a volcanic caldera collapse basin perhaps localized by this structure. The fault along the west side of Iligan Bay coincides with the sharp Moro Gulf reentrant of the Celebes Sea, which may also be partly controlled by faulting.

The outline of the Mindanao Sea basin thus appears to be determined by complex geologic structures. The eastern end of the basin is determined by a series of horst and grabens which have been elevated or depressed between branches of the Philippine rift zone. The western end of the basin is constricted by volcanic deposits of southernmost Negros, the volcanic base of Siquijor Island, and by volcanic deposits of

Mts. Ampiro and Malindang of northernmost Zamboanga Peninsula. The southern side is influenced by at least four and possibly five major faults. The sharp profile south of Bohol Island is probably the result of east-west faulting. Although no faults of this trend were noted during the Corby survey (1940), examination of aerial photographs of the southern coast shows that the coastline is at least partially controlled by faulting.

Camotes Sea basin.—The Camotes Sea basin is a small irregular depression between Cebu, Bohol, and Leyte islands. The three northeasterly trending islands of Ponson, Poro, and Pacijan, known as the Camotes group, lie near the center of the basin. The deepest portions of the basin, about 460 fathoms, are in two areas, one north and the other south of the Camotes Islands.

From regional mapping the Tertiary sediments of western Leyte dip west and pass beneath the basin. The Tertiary sediments of Cebu, youngest of which is the Carcar limestone (Pliocene), dip east and likewise pass beneath the basin. The sharp southern profile of the basin seems to be due to growth of massive coral reefs along the margin of the Danajon banks of the Bohol shelf. From a sharp line extending in a northeasterly direction from Capitancillo Island, the northern side of the basin shoals rapidly from 450 fathoms to 140-180 fathoms, suggesting displacement by faulting.

South Sibuyan Sea basin.—The South Sibuyan Sea basin is located north of Panay and is enclosed by Tablas, Romblon, and Sibuyan islands and by the Visayan shelf which extends between Masbate and Panay islands. The western part of the basin descends to depths of 740 to 750 fathoms.

The basin is roughly elliptical in shape. Its western margin adjoining Tablas Island is very steep and the position and trend of the escarpment coincides with the projection of the fault controlling the western coast of Panay. Along the west coast of Tablas, a similar, though less pronounced, offshore profile exists. Opposite Buruanga Peninsula of Panay, a local closed basin, passing to maximum depths of 553 fathoms, suggests that the area has been depressed. The location and remarkable alignment of all these features indicate that Buruanga Peninsula of Panay, and Tablas Island, constitute a horst elevated between two major faults.

The South Sibuyan Sea basin was formed evidently by strong subsidence along the eastern fault.

North Sibuyan Sea basin.—North Sibuyan Sea basin is a similar, though larger, northwesterly trending elliptical depression that lies between the Tablas-Romblon-Sibuyan island group, Masbate and Marinduque islands, and the Bondoc Peninsula of Luzon. The central portion of the basin passes to maximum depths of 985 to 1,000 fathoms. Judging from submarine profiles its western side is partially controlled by a fault which is the continuation of that along the western side of the South Sibuyan Sea basin. The throw of the fault appears to be decreasing in northward direction.

Ragay Gulf basin.—Ragay Gulf basin is a narrow elongate closed basin which lies between Bondoc Peninsula and the southern mainland of Luzon. A narrow trench passing to depths of 285 to 330 fathoms, extends obliquely across the basin from Caurusan point, Camarines Sur, almost to Lian Point on Bondoc Peninsula. The trench is bounded by two gently curving escarpments of steep submarine profile, which are believed to be of fault origin. The trench is probably a graben that has been depressed between faults which are subsidiary to the Philippine rift zone.

Tañon Strait basin.—The Tañon Strait basin is a narrow elongate closed depression which lies between Cebu and Negros islands. Maximum depths of 260 to 300 fathoms are found along the axis. The Carcar limestone formation (Pliocene) on the two islands dips respectively west and east toward the axis of the depression. Although off-shore profiles are moderately steep, until more satisfactory evidence for faulting is available, the basin is considered to be a synclinal downwarp between the two islands.

CONTINENTAL AND INSULAR SHELVES

In several areas shelves of surprisingly large dimensions border the islands. Those that are located on or adjacent to remnants of the supposed Sundaland sub-continent, may correctly be called continental shelves. On the other hand, those that adjoin islands of the principal sigmoidal ridge may not be continental shelves, but rather "insular shelves." Until the geology of ridge structures is better understood it is believed there is some value in keeping in mind this distinction.

The shelves vary from 5 to 80 fathoms in depth and coral reefs grow in profusion in characteristic clump-like fashion, resulting in considerable irregularity of the shelf surfaces. In general the shelves slope gently seaward from the islands or land masses, and at depths of 80 to 100 fathoms, they break

abruptly into deep water basins, troughs, etc. Situated as these shelves are in a region well known for tectonic instability, it is rather surprising that they are so numerous and widespread, and that they are found at such comparatively uniform depths.

From our present understanding of the geology and history of the Philippines, the Sundaland shelf, Calamian-Cuyo shelf, and the northeast Borneo shelf are the closest representatives of continental shelves. The remaining shelves are considered for the present to be insular shelves. The continental shelf areas are described first.

Sundaland shelf.—Sundaland shelf is located west of the Palawan trough, and appears to be a depressed continuation of north Borneo. It is rather unfortunate that little charting and sounding has been done in this area. Sufficient information is available, however, to indicate that the sea is probably less than 100 fathoms deep over very great areas. Numerous coral reefs jut up to or nearly to present sea level. The extensive shelf immediately west of Palawan is evidently correlative with it, at least in elevation, if not in origin.

Much of the area was probably exposed during the Pleistocene glacial stages and with the subsequent positive eustatic shift of sea level, the region became inundated and coral reefs have grown commensurate with the rise of sea level. The area is now free of seismic activity and appears to be tectonically stable.

Calamian-Cuyo shelf.—The Calamian-Cuyo shelf takes its name from the two principal island groups that are situated within it and is located in the region between northern Palawan, Mindoro, and Panay islands. The shelf has an area of about 12,500 square miles and over great areas its depth varies from 30 to 60 fathoms.

The northeastern boundary of the shelf, opposite Mindoro Island, is most irregular and appears to have developed by depression of the floor of the shelf, combined with irregular upward growth of coral reefs from the subsiding floor. Maximum depths of 650 fathoms are recorded in an irregular closed depression south of Apo Island. Elsewhere the shelf breaks abruptly into depressions 100 to 300 fathoms greater than the floor of the shelf itself. The northwestern margin is determined by the northward projection of the Palawan graben. The shelf is bordered on the east by the Antique trough west

of Panay Island and the southern margin breaks abruptly into the Outer Sulu Sea basin.

Northernmost Palawan and Calamian islands are composed mainly of highly folded late Mesozoic or early Tertiary quartzites. These are very deeply eroded and the region now displays typical shorelines of submergence. The Cuyo Islands are partly volcanic and partly of coral reef structures. Evidently not long ago northern Palawan and the Calamian island group stood at a high position relative to sea level to permit a subaerial drainage pattern to develop. Due either to positive eustatic shift of sea level or to actual depression of the area, present land areas show shorelines of submergence.

The Northeast Borneo shelf.—The northeast Borneo shelf extends from 50 to 70 miles northeast from the Borneo coast and forms a single coextensive surface for two hundred miles from southern Palawan and Balabac islands, to the Sulu archipelago. In general it slopes gently outward from the Borneo coast and like most continental shelves, its outer edge is determined by a sharp break in profile between the 100 and 200 fathom line. The surface of the shelf, particularly in the shallow inshore areas, is thickly studded with coral reefs. The northeast coast of Borneo from the study of maps appears to be strongly submergent.

The remaining shelves are considered to be of the insular type.

The Visayan shelf.—The Visayan shelf underlies the shallow Visayan Sea in the area between Masbate, Panay, northern Negros, and northern Cebu islands. Its depth rarely exceeds 25 fathoms. The shelf in effect joins the central Visayan islands into one single mass. Much of this shelf is underlain by coral reefs.

The Leyte and Samar shelves.—The Leyte shelf underlies Leyte Gulf between Leyte and the southern part of Samar Island and extends southward between Dinagat and Siargao islands and dies out against the northeast coast of Mindanao.

The Samar shelf lies west of northern Samar and passes through the San Bernardino Strait to connect with the narrow shelf north of the island.

Both pass to similar depths of 40 to 60 fathoms, and both break sharply into the Philippine deep to the east. Both comprise effective local barriers to the entry of deep level waters from the Pacific Ocean into the area of the archipelago.

The Polillo-Catanduanes shelf.—Between Polillo and Catanduanes islands lies a suprisingly large shelf which extends 30 to 40 miles north from the Camarines coastline of Luzon. Much of the shelf is only 20 to 25 fathoms deep. Along its northern edge, the surface breaks sharply into the depths of the Luzon reentrant. Like the Leyte and Samar shelves, the Polillo-Catanduanes shelf also lies between the Philippine rift zone and the Pacific Ocean. All in effect knit this area into an intergrated physiographic-structural unit.

ISTHMIAN RIDGE LINKS

The Balabac-Palawan-Calamian island group forms an isthmian link between northeast Borneo and the central Philippines. In similar manner the Sulu archipelago ridge comprises an isthmian link between Borneo and Mindanao islands in the southern Philippines. The Palawan link owes its present form to late geological events. The Sulu archipelago ridge possesses striking regional geologic structure.

The Palawan isthmian ridge.—The Palawan ridge extends as a rectilinear mass for a distance of more than 400 miles between North Borneo and Mindoro. Although Palawan Island is only 20 to 30 miles wide throughout much of its length, if the shallow shelves adjoining the coast are included, the isthmian ridge proper is 50 to 80 miles wide, and accordingly is much more massive than indicated by the island itself.

Palawan Island is composed predominantly of pre-Tertiary basement rocks. In the north-central part, the basement rocks consist of chlorite-feldspar schists, and these are intruded by serpentized peridotite and by local granitic masses. At the northern end of the island these rocks are overlain by thin-bedded, strongly folded quartzites. Southern Palawan is underlain by highly contorted cherts, phyllites, and slates intruded mainly by serpentinites. These are overlain by moderately folded siliceous sandstone and locally by limestone, of lower Miocene age. Upper Tertiary formations are largely absent, suggesting that the island has been dominantly emergent since that time. The form of the island seems to have been strongly influenced by the development of the Palawan fault trough to the west.

Although much of the present island possesses either an emergent or neutral shoreline, the northern end of the island and the Calamian Islands show strongly submergent features. Between the Calamian Islands and Mindoro the sea floor pas-

ses to depths of 400 to 600 fathoms. The shallowest crossing in the area is 240 fathoms. If a land bridge once extended across to Mindoro to account for the Bornean affinities of its fauna and flora, it is necessary to prescribe either or both strong subsidence and strong eustatic shifts of sea level in recent geological time. Actually the shallowest submarine crossing to Mindoro Island in any direction at the present time is across of Verde Island passage (176 fathoms) which is located north of Mindoro Island.

Little can be positively discerned of the structure of the area east of Palawan Island, i. e., beneath the Outer Sulu Sea basin. Some might argue that it shows collapse features and the present floor may at one time have stood near sea level. Certainly at a number of points around the margin of the basin, excessively steep profiles are evident. For the present, however, we have no geologic evidence requiring that the area once stood at or above sea level and since has subsided as much as 800 to 1,000 fathoms (4,800 to 6,000 feet). Epicenters are few in number and widely spaced, indicating that the region is now stable.

The Sulu archipelago isthmian ridge.—The Sulu archipelago between Zamboanga Peninsula and northeast Borneo consists of a large number of islands scattered over a distance of 200 miles. Viewed from the standpoint of submarine topography, however, that part of the ridge upon which the archipelago occurs is only a segment of the longer ridge that also includes Zamboanga Peninsula. From this point of view, the ridge comprises a structural unit 330 miles in length connecting Borneo with the main body of Mindanao Island at the narrow, probably structural, waistline between Iligan Bay and the Moro Gulf reentrant. The ridge maintains a remarkably uniform trend, and a width of about 75 miles. At both margins of the ridge the profile breaks precipitously into the Sulu Sea basin to the north and into the Celebes Sea basin to the south.

Looking closely at the submarine topography of Sulu archipelago, we see that the islands are distributed along two prominent marginal ridges. Between them is an elongate closed depression. The floor of the central depression passes to maximum depths of 300 fathoms. Fairly distinct gaps cross both ridges, in Sibutu passage west of Tawi-Tawi Island, and between Pearl bank and Talantam shoal to the north.

The southern belt includes the largest and the greatest number of islands. They are composed mainly of Tertiary and

Quaternary volcanics and basement crystalline rocks, with subordinate amounts of Tertiary sediments and reef limestone. The northern belt of islands is composed almost entirely of reef limestones of low elevation. From physiographic and geologic evidence the tectonic axis of the Sulu archipelago ridge appears to be situated along its southern edge. On Zamboanga Peninsula the tectonic axis crosses over the northwestern side of the ridge. Per contra, the northern side of the Sulu archipelago and the southeastern side of Zamboanga Peninsula, particularly in the area of the Sibuguey Bay and the southern ends of Sibuguey and Baganian peninsulas, are tectonically low areas.

On the basis of the present configuration of the sea floor, the shallowest water covering the isthmian links between the Philippines and Borneo are in the Sulu archipelago. Sibutu passage is 148 fathoms deep, and the remaining passages across the ridges are shallower. Thus with a eustatic shift of sea level of say 150 fathoms the Philippines would become land-connected with Borneo. Palawan and Mindoro islands, meanwhile, would still be separated by bodies of water nearly 100 fathoms deep.

SUBMARINE TOPOGRAPHIC EXPRESSION OF THE PHILIPPINE RIFT ZONE

The so-called Philippine "master fault" has been traced and described by several writers including W. D. Smith (1924), W. C. Repetti, S. J., (1934), Bailey Willis (1937), and A. Alcaraz (1949). Each introduces slight variations according to the data at hand and his interpretation of such data. Doubtless some variation, particularly with reference to the geographic position of the structure at all points, results from incomplete understanding of the structure.

Beginning at the northwest, the first clear expression of its trace is in the area of Alabat Island, south of Polillo Island. The long narrow Alabat Island is described by Corby (1940) to be underlain by two rock groups, by pre-Tertiary crystalline basement rocks on the northeast side and by upper Miocene conglomerate along the southwest side. The extreme elongation of the island is suggestive that its form is controlled by marginal faults. Along the northwest projection of the island, a closed depression in the Polillo-Catanduanes shelf descends 50 to 60 fathoms below the average level of the submerged shelf itself. This might be interpreted as a sag basin

controlled by faulting. Further to the northwest, little physiographic evidence for its presence on the shelf is discerned.

Just south of Dingalan Bay the offshore northeastern coastal fault of Luzon and the possible east-west fault at the base of the Polillo-Catanduanes shelf converge toward it and may merge with or actually intersect it. From Dingalan Bay inland, however, a prominent fault zone passes inland from the coast in a northwesterly direction and along it is a pronounced valley-like depression that merges with the Central Valley of Luzon near the town of Rizal, Nueva Ecija. The region northeast of this fault has been elevated several thousand feet, thus producing the sharp, rectilineal range front along which are located the towns of Dingalan, Bituok, Antipolo, Macabacay, Rizal, San Jose, Lupao, Umingan, Natividad, and San Nicolas.

Both San Nicolas and San Miguel are situated in reentrants where the zone of rifting begins to lose its identity. The topography in these reentrants rather indicates that branch faults split off in northerly direction into the range proper. There appears little evidence that the fault continues through to the Lingayen Gulf because in the area of the Agno and Bued river canyons, the structure of the range is a large monoclinical arch in a thick section of Tertiary sediments.

This described landward fault may be either a portion of the Philippine rift zone, or conceivably a northwestern seismically active branch of perhaps the more important, but presently inactive, portion extending along the northeast coast of Luzon. Much is to be learned of the northern continuation of the rift zone both by geological mapping and in the third dimension, from seismographic study of earthquake shocks that occasionally take place along it.

From Alabat Island southward, the rift zone cuts through the narrow waistline of Luzon near Calauag, Tayabas, and continues along the axis of Ragay Gulf. From Bantain Point near Gutusan, to Sibuno Point near Cotmo, on the Camarines coast, the sharp lineal coastline is clearly defined by an east-west trending offshore fault. As shown on detailed sounding charts, a second fault about 5 miles southwest of the coastal fault and parallel with it, has caused the intervening block to be depressed as a graben beneath Ragay Gulf.

The rift zone thence passes closely to the northwest coast of Burias Island. The offshore profile is again very sharp. In the pass between Burias and Ticao islands, a sharp closed basin almost 600 fathoms deep indicates strong depression of

the sea floor, probably as a fault-controlled sag basin. In this area the rift zone crosses over to and thence passes along the south side of Ticao Island, where again steep offshore profiles are found off the coast. The depression between Ticao and Masbate islands appears to be bounded by this and another fault located along the northeast coast of Masbate. Both Burias and Ticao islands, relative to adjoining areas, are structurally high areas and the islands themselves may owe their elevation to uplift between complex marginal faults which are also part of the rift zone structure.

The southern part of the northeastern coast of Masbate is also strongly influenced by the rift zone. Between Dimasalang and Catsingan, the principal rift appears to pass two to three miles inland from the coastline as indicated by a strong lineal depression behind coastal hills in which is developed a pronounced subsequent drainage. Along, but offshore, from the coast, a parallel subsidiary fault possibly accounts for its rectilinear trace and its offshore profile.

Only on Leyte Island does volcanism appear to have broken out along and to have been controlled by the rift zone. Two prominent dormant volcanic structures on Biliran Island, and several along the central highlands of Leyte appear to be situated at least over one of the parallel faults comprising the rift zone. While little detailed geologic mapping has been done in this part of Leyte the present active line of rifting appears to pass into Leyte Bay on the north and to follow along the southwestern side of the axial highland area. In southern Leyte, the rift zone adopts a multiple parallel fault pattern that continues for some distance southward into northeastern Mindanao. Sogod and Cabalian Bays adjoining Panaon Island, according to submarine configuration, are clearly graben structures between marginal faults. Panaon Island is a horst block between the two grabens. A western fault diverges from the zone of parallel faults and passes along the eastern side of Gingoog Bay, north-central Mindanao.

As mentioned before, at least three important parallel faults pass along the western side of Surigao Peninsula. The eastern and central fault appear to give form to the Lake Mainit graben. The central and western fault border the horst block represented by the western range. South of Butuan Bay, little geologic study has been conducted, and the trace of the respective faults is not known, although they are believed to be located along the east side of the broad depression of the Agusan River val-

ley. This depression carries through to Davao Gulf, and doubtless the master rift zone in some way has exercised structural control on the deep Davao Gulf reentrant as well as the long narrow Davao Peninsula. From the position of submarine earthquake epicenters, the principal rift structure probably passes along the east side of the reentrant and at the western base of Davao Peninsula.

Supplementing the strong topographic and structural evidence of rifting on the various islands, we thus find considerable topographic expression of the structure along its trace beneath the sea. The evidence consists of sag basins, graben troughs, horst blocks, and abrupt lineal escarpments. In northern Leyte particularly, volcanism has broken out along the rift to form Biliran Island and possibly several smaller islands to the north, as well as several volcanic structures on the Island of Leyte.

On Plate 2, several earthquake epicenters are clearly disposed along the rift. However, it is also evident that the rift is not a single fault, and the terms "master fault", or "Philippine fault", or "Visayan fault" fail to express the complexity of the structure. It is in fact a complex zone of rifting composed in many places of several parallel faults of diverse direction and amount of throw, interalia. The attitude of the many faults and of the rift zone is not yet known. Along its trace, the component faults probably lace in and out, and some doubtless branch quite sharply from it. The structure in fact is probably no less complex than the better known San Andres rift of California. It is for this reason that the term "Philippine rift" is much to be preferred.

SEISMIC EVIDENCE FOR FAULTING AND RIFTING

Gutenberg and Richter (1949) estimate that about one million earthquake shocks take place in the earth's crust each year. The total calculated annual energy release is estimated to be approximately 12×10^{26} ergs. When it is considered that the energy release of a modern atomic bomb is officially reported to be equivalent to 20,000 tons of T.N.T., or 10^{21} ergs, the total annual energy release by all earthquakes is

$$12 \times 10^{26}$$

equivalent to ———, or to 1,200,000 atomic bombs.

$$20^{21}$$

The average energy release per earthquake shock, using the above data, is equivalent to 1.2 atomic bombs. Although perhaps 80 to 90 per cent of the one million shocks are so feeble

or are so distant that they are neither felt by man nor recorded by instruments, the remaining earthquakes release prodigious quantities of energy. In extreme cases Gutenberg and Richter estimate that a single class "a" earthquake, such as the Indian earthquake of 1897, the Lisbon earthquake of 1755, or the Alaskan earthquakes of 1897, release nearly twice the average amount of energy expended for the entire earth by earthquakes in one year. In other words the energy release of a single exceptionally large earthquake may be equivalent perhaps to 2,000,000 atomic bombs! Although mankind is now perturbed over the fearful possibilities of the atomic bomb, many cities, including Manila, have been and are now situated over areas where earthquakes of this magnitude have occurred, and will inevitably occur again with the mere passage of time!

Earthquakes are classified according to their magnitude (energy release) and their depth of focus. In earlier years the Rossi-Forel scale was widely used for classification of earthquakes according to magnitude, but this has serious defects of personal equation. From instrumentally determined records, it is now possible to calculate the position of earthquake foci, their depth below the surface, and their energy release. These data provide a uniform basis for comparison between earthquakes whithersoever dispersed, whatever their time of origin, and at the different levels within the earth's crust.

From earthquake data tabulated by Gutenberg and Richter for the period 1900 to 1945, the Philippine archipelago including Celebes Island is among the more seismic areas on the face of the earth. It is exceeded perhaps only by Japan and north-western South America. Masó (1926) states that between 150 to 250 earthquakes sensible to observers are recorded in the Philippines every year; of course many more take place that are not actually observed. In years of extraordinary activity, as many as 450 are observed. The great majority of Philippine earthquakes are of shallow focus, and accordingly produce comparatively strong surface effects. Deep focus earthquakes occur only in Mindanao and beneath the Celebes Sea to the south.

In order to ascertain if any relationship exists between physiographically indicated submarine rifts or faults and earthquake epicenters, a seismic map for the Philippines was prepared (see Plate 2). Locally recorded and determined epicenters for the period 1920 to 1935, as determined by Repetti,

were first plotted. These were carefully screened as to time and place of origin, and the epicenter data furnished by Gutenberg and Richter (1949) were substituted in those instances where data for individual earthquakes were duplicated. The latter are believed to have higher technical verification. About 110 locally determined earthquake epicenters and 150 epicenters determined by overseas seismographic stations are plotted. This partial record for the period 1900 to 1945, consisting of 250 epicenters, gives representative basis for locating some of the more active faults or rifts of the archipelago. Because the position of some volcanic centers are also controlled by faults or rifts, these were also plotted. The results are surprising in several respects and invite brief comment.

Earthquake epicenters are preeminently distributed along the principal sigmoidal Philippine ridge, but in a more pronounced or sharper, sigmoidal curve than that of the ridge itself. In northern Luzon, the majority of epicenters are situated on the western side of the island and off the China Sea coast. In the central Philippines, epicenters are broadly distributed. In the southern part, the preponderance of epicenters are situated in eastern Mindanao with an extremely heavy concentration on the slope between the coast and the axis of the Philippine deep; some occur in the trough, and a few east of it. Numerous epicenters are found along both submarine extensions of the main sigmoidal ridge, to the north and south. A rather surprising number occur beneath the floor of the Celebes Sea. On the other hand the Sulu archipelago, the Sulu Sea, and the Palawan areas are almost devoid of epicenters. A similar dearth of epicenters is found in the area northeast of Luzon. Only occasional epicenters are found along the northeast coast. The central part of the China Sea basin is completely inactive.

There are two major rift zones in the Philippines which, if they existed in more populated areas and received comparable publicity, would be of the same class as the San Andres rift zone of California. Both are more than 500 miles long.

The Philippine rift zone whose course has already been described, causes seismic disturbances of frequency comparable to the San Andres rift. The southern and central portions of the rift appear to be more active than the northern part. The Agusan valley earthquake of July 12, 1911, for example, was

of only slightly smaller order of magnitude than the San Francisco earthquake of April, 1906.

If the apparent fault that borders the northeast coast of Luzon is a part or branch of the Philippine rift, this portion is quite inactive. The northern part of the Philippine rift that passes inland and follows the escarpment inland from Dingalan Bay, also appears to be comparatively inactive. In the Baguio region, seismicity increases considerably. The faults in this region, as indicated before, may be horsetail branches of the rift zone where it begins to lose its identity.

By far the most active zone in the Philippines is that related to the Philippine deep bordering Samar and extending along the east coast of Mindanao. Possibly as many as one half of the stronger shallow focus shocks recorded in the Philippines occur in this area. It is also noted that many foci of intermediate shocks occur somewhat to the west of the belt of shallow focus epicenters. Deep focus epicenters are located much farther to the west about at the longitude of central Mindanao. This offset belt or zonal arrangement of foci, discounting foci related to the interposed Philippine rift zone, is now recognized to be quite typical of many of the arcuate structures around the Pacific. These are beginning to be interpreted to be caused by deeply penetrating reverse shears that form in response to compression from the continental areas toward the passive ocean basins. The shears emerge, it is believed, between the island arcs and the fore-deeps fronting them. This typical pattern appears to be limited to the Mindanao sector of the Philippines. Evidently the northern part of the structure is comparatively inactive.

Several epicenters are situated along the indicated fault lines forming the Antique trough and the Buranga Peninsula-Tablas Island horst. Although the epicenter of the class "a" shock that caused extensive damage in Panay in January, 1948 was believed to have been located in west-central Panay, it may in fact be related to this prominent zone of rifting. The instrumentally determined focus is not yet available.

The Sulu Sea rift zone and the indicated faults bounding the Palawan garben trough are completely inactive.

The prominent indicated fault along the south side of the Lubang Island and extending inland into the Verde Island passage north of Mindoro Island, has a number of epicenters along its trace.

The prominent indicated fault zone off the Zambales coast appears to be confirmed by the existence of a lineal series of epicenters along its trace. It is quite probable that movements on this fault and on the immediately preceding fault give rise to the earthquakes that are felt most strongly in Manila.

The numerous and widely distributed epicenters of northern Luzon and to the north along the submarine ridge, as well as those south of Mindanao are not readily correlated with any evident submarine structure.

GENERAL OBSERVATIONS

Fundamental understanding of the geologic history and structure of the Philippine archipelago involves not only correct reading of the facts recorded in the rocks exposed on land areas, but also an adequate understanding at least of the geology of the much larger areas that lie below sea level.

To obtain information regarding the areas beneath the seas is not easy. We are forced to rely in large part on indirect sources of information such as marine soundings, seismology, geodesy, oceanography, and inferences drawn from the geology of land areas. Comparatively objective data from these sources, however, must then filter through the personal equation of human interpretation. Despite the weakness of interpreted results, serious effort is necessary, if not indispensable, if ever we hope to understand the geology of the region as a whole.

As pointed out by Umbgrove (1947), and by many others before him, "island arcs are among the most challenging features of the earth's surface." Although island arcs have intrigued geologists for a long time, perhaps much of the long distance interest arises more out of curiosity than from the light of knowledge or experience. Nevertheless, despite that most island arcs have not received their deserved geological study, the Japanese, East Indies, and perhaps the Philippine arcs have been studied by more than average amount. Certain similarities and generalizations have been recently drawn in two notable books by Umbgrove (1947) and by Gutenberg and Richter (1949).

Island arcs, in plan, show a marked concavity toward continental areas and a corresponding convexity toward the ocean basins. Most possess a marginal deep-sea trough in front, between the island arc and the floor of the ocean basin. Strong negative isostatic anomalies are found over the trough and

the landward side of the trough. Earthquakes of shallow focus are heavily concentrated along the outer edge of the arc, particularly between the coast and the axis of the trough. Volcanism is exceedingly active along the arc, and the volcanic belt frequently lies near the outer landward edge of the arc. The belt of volcanism approximately coincides with a belt of epicenters of intermediate depth. Deep focus epicenters occur as a belt still further removed from the outer edge of the arc. From gravity observations, it is a fact of observation that the island arcs are compensated isostatically, and from our knowledge of internal regional geology, this condition has existed at least since Mesozoic time, and in certain arcs at least since the Paleozoic or before. Nevertheless, if we view the distribution of earthquake epicenters in section, the essentially compensated arcs appear to be bound on their outer edge by active and deeply penetrating steeply inclined shear zones, that suggest compression of the arc from the continent toward the passive ocean basin. The area within the concave side of the arc, on the other hand, is comparatively stable and shows few features of the outer edge. An arc may be simple, or it may be compound, or indeed it may be complex, in which a younger arc has been superimposed upon an older arc system. Arcs may be immediately contiguous to the adjoining continent, or they may be considerably removed.

These generalizations appear to hold true for the southern part of the Philippine archipelago, but the northern part of the archipelago appears to show important departures, unless it is accepted as Gutenberg and Richter suggest, that the arc front of northern Luzon is reversed and faces the continent. From our knowledge of regional geology, however, this suggestion is difficult to accept and in the absence of pressing reasons to the contrary it is preferable to believe that the northern portion is a comparatively negative segment of an arc system. In an earlier paper, the present writer (1950) adduced certain evidence tending to indicate that northern Luzon constitutes part of an older southeasterly convex, arc system, while the southeastern islands adjoining the Pacific are part of a younger, northeasterly convex, arc system. Under this interpretation, northern Luzon might be considered an area common to a complex arc system.

From no more than a cursory examination of a regional bathymetric map (see Fig. 1), it is apparent that the Philippine archipelago is the northern continuation of that complex

area of the central East Indies in which geologic structures suddenly adopt sharply diverging trends from the predominant east-west regional trends of the East Indies as a whole. Although Umbgrove has brought together a vast amount of diverse data and has synthesized it well into a logical pattern, this area of the Wallace or Webber lines is certainly one of unusual structural complexity and may require a great deal of study before it is well understood. The fact that this area of the East Indies, unlike the areas to the east and west, is profusely intruded by peridotites and serpentinites suggests that exceptional tectonic events have taken place. The equally profuse intrusion of peridotites and serpentinites in the Philippine archipelago also implies exceptional conditions, and close geological affinity of the two areas.

Whether the Philippine archipelago may at one time have consisted of a former large land area that has since broken up into an insular pattern, as Umbgrove suggests in the case of western Celebes and Borneo for instance, seems doubtful except possibly in the local cases where Palawan Island became separated from Sundaland by development of the Palawan trough, or where Panay Island became separated from the Calamianes-Cuyo shelf by the development of the Antique trough. For the present it would seem that the principal sigmoidal ridge of the Philippines and the major deep sea basins are original and primary features. These features of course have been and are being modified from time to time by mountain uplift, downwarping, and by graben faulting but, it is believed, always within reasonable limitations of the concepts of isostasy.

REFERENCES

- ALCARAZ, A. P. The major structural lines of the Philippines. *Philip. Geologist* 1 2 (1947) 13-17.
- CORBY, G. W., et al. Geology and oil possibilities of the Philippines. Manila, Bureau of Mines. (Unpublished manuscript).
- GUTENBERG, B. and C. F. RICHTER. Seismicity of the earth and associated phenomena. Princeton, Princeton Univ. Press, 1949. 274 p.
- HESS, H. H. Major structural features of the western north Pacific, an interpretation of H.O. 5485, bathymetric chart, Korea to New Guinea. *Geol. Soc. Amer. Bull.* 59 (1948) 417-445.
- IRVING, EARL M. Review of Philippine basement geology and its problem. *Philip. Jour. Sci.* 79 (1950) 259-295.
- KOSSINNA, E. Die Erdoberfläche. *Handbuch der geophysik* 2 3 (1933).
- LAWSON, A. C. Insular arc, foredeeps, and geosynclinal seas of the Asiatic coast. *Geol. Soc. Amer. Bull.* 43 (1932) 353.

- MASO, M. S. Ancient Philippine earthquakes 1585-1865. *Seism. Bull. of Manila Obs.* (1926) 61-99.
- REPETTI, WM. C. Philippine earthquakes, marine epicenters, 1920-1929. *Publication of the Manila Observatory* 3 (1931) 199-203.
- REPETTI, WM. C. Tectonic lines of the Philippine Islands. *Seism. Bull. of the Manila Obs.* (1934) 57-70.
- REPETTI, WM. C. Philippine earthquake epicenters. *Seism. Bull. of Manila Obs.* July-December, 1930.
- ROOTHAAN, H. PD. Geologische en petrographische schets der Talaud en Nanoesa eilanden. *Jaarboek mijnwezen Nederlandsch-Indie* (1925) 174-218.
- SMITH, W. D. The geology and mineral resources of the Philippine Islands. Manila, Bureau of Science. Publication No. 19, 1924, 559 p.
- UMGROVE, J. H. F. Pulse of the earth. The Hague, Martius Nijoff, 1947. 358 p.
- VAN BEMMELEN, R. W. Geology of Indonesia 1 (1949) 1-732.
- WILLIS, BAILEY. Geological observations in the Philippine archipelago. *Nat. Research Council, Bull.* 13 (1937) 1-127.

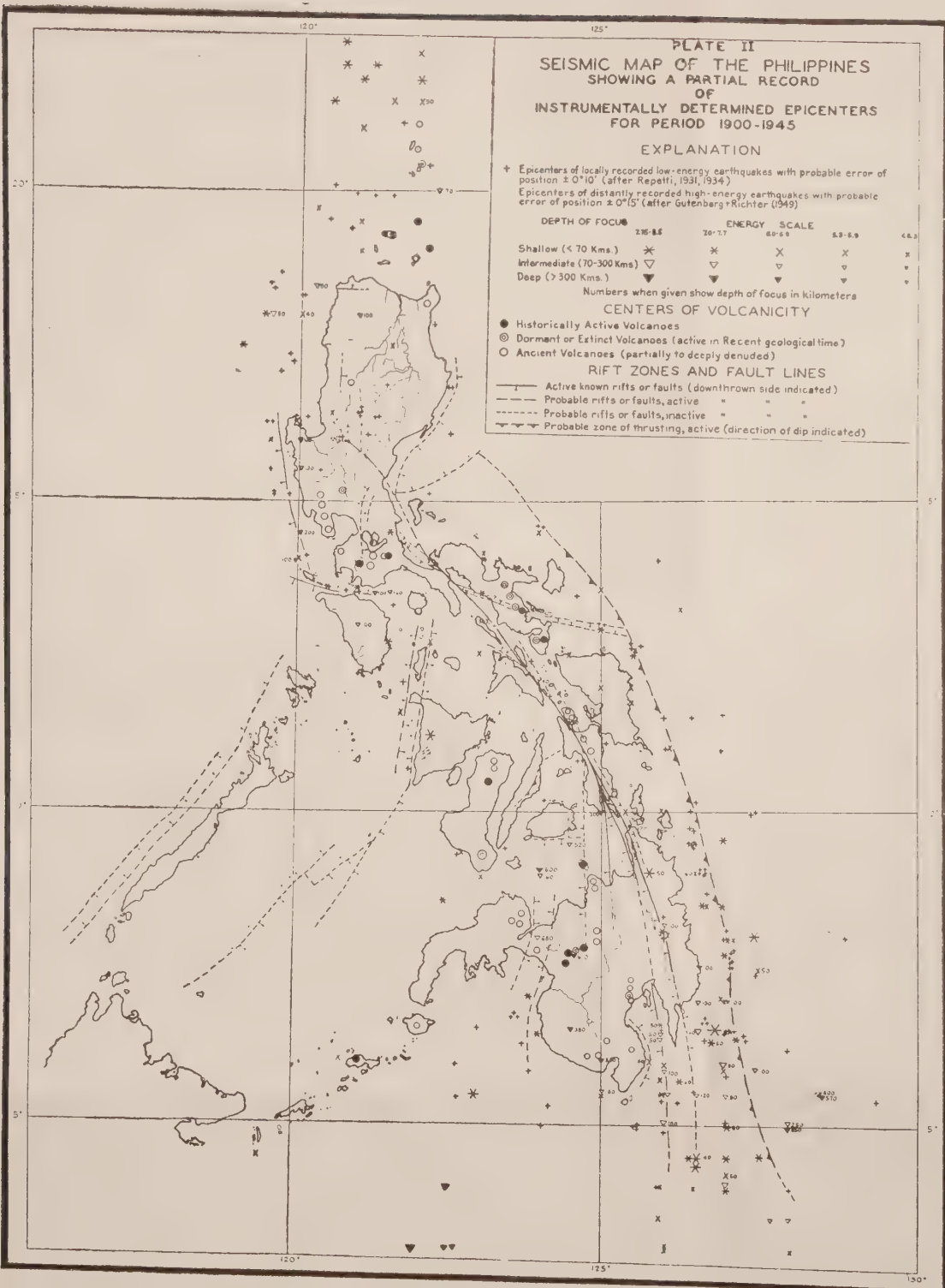


PLATE 2.

BOOKS

Books reviewed here were received from time to time by The Philippine Journal of Science and acknowledged in this section.

Arithmetic for Colleges. By Harold D. Larsen, Ph.D. New York, The Macmillan Company, 1950. 275p. Price, \$3.75.

This book will be a valuable aid for college students who intend to teach with professional proficiency arithmetic in the elementary grades. The author has dealt extensively not only in the historical background but also in the explanations of the principles, applications and short methods of arithmetical processes. For the interest of the readers, the author has included some recreational incidents.

An important feature of this book is the chapter on approximate numbers and computations in which the governing principles are carefully presented. Mention has to be made of the chapter on Introduction to the Slide Rule, which is not often included in standard arithmetic books. This chapter will be of great help to students planning to take an engineering course. As a whole, this book is highly instructive.—N. F. M.

Kinetics of Chemical Change in Solution. By Edward S. Amis. New York, The Macmillan Co., 1949. 332p. Price, \$5.00.

This book covers the field of reaction kinetics more extensively than what authors of textbooks in physical chemistry normally cover. It is the purpose of this book to give students the fundamental training in the subject of rate processes in solutions.

After presenting a brief introductory chapter covering the two fundamental steps toward the understanding of reaction kinetics, namely, the mass action law and that covering the temperature coefficients of reaction rates, it goes on to formulate the Debye-Huckel theory for activity coefficients of ions and electrolytes as well as the Debye-Jaffe theory concerning polar molecules and liquid dielectrics. The Debye-Huckel theory as discussed in this text covers completely the mathematical derivation of the expression for activity coefficients of ions and electrolytes as well as the potential arising from the ionic atmosphere of all ions in solution. Then it goes on to explain other theories like Bromsted's theory on "Salt Effect" or the effect of the addition of neutral salts upon the activities of the reacting ions.

This book which is carefully and thoroughly presented by the author will be a valuable aid to the chemists interested in chemical kinetics.—C. E. L.

Hydrology. By Daniel W. Mead. Second edition—First impression, revised and enlarged by Mead and Hunt, Inc., New York, McGraw-Hill, 1950. 728p. Price, \$7.50.

To those studying nature's phenomena, work on hydrology, like that of Daniel W. Mead, should attract their attention. According to this author, "hydrology in its broadest extent treats of the properties, laws, and phenomena of water, of its physical, chemical and physiological relations, of its distribution and circulation throughout the habitable earth, and the effect of this circulation on human lives and interests." He further stated that "this circulation of the water above, on, and within the earth's crust, is as important and necessary in geological change and development as in the circulation of the blood in the animal body or in the circulation of the sap in vegetable life." Hence the importance of the subject in our daily lives.

The book has the following chapters: Introduction, Water—Its Occurrence, Utilization and Control, Some Fundamental Theories, Winds and Storms, Hydrography, Atmospheric Moisture and Evaporation, Precipitation, Rainfall Measurements and Records, Annual Rainfall in the U. S. and its Variation, Seasonal Rainfall in the U. S. and its Variation, Great Rainfalls, Droughts, Rainfall and Altitude, Geological Agencies and Their Work, Ground Waters, Steam Flow or Runoff, Variations in Runoff or Stream Discharge, Estimating Runoff, Floods and Flood Flows and the Application of Hydrology. There are 728 pages including an index.

As a textbook, students will find the book very understandable and readable, and as a reference for teachers and practitioners in hydrology it is a very good companion. The author presented clear expositions of the different subjects discussed, together with numerous tables, graphs and up-to-date references. He should be congratulated in putting in book form the scattered data and information on hydrology, including his experience in practice. It is doubtful whether any book on the same subject has treated the different topics more fully. The book as a whole, is a handy guide for agriculturists, meteorologists, and agricultural, civil, power and hydraulic engineers.—G. O. O.

Analytical Chemistry of the Manhattan Project. Edited by Clement J. Rodden, N. H. Furman, E. H. Huffman, L. L. Quill, T. Duane Price, and J. I. Watters. First edition. New York, McGraw-Hill, 1950. 748p. Price \$6.75.

Analytical Chemistry of the Manhattan Project, by the editors, was mainly prepared for uranium chemistry for the analysis of materials used in the Manhattan Project. Existing modified and new methods were utilized for the analysis of uranium ores and materials containing either uranium, thorium, plutonium with their impurities.

The impurities may be several for all the known elements of the Periodic Table. In such cases, nearly all the existing and new methods were tried. These may involve volumetric, gravimetric, basometric, electrometric, potentiometric, physical and spectrometric methods. All have one aim in view—the purification of the radioactive materials for the Project.

Some of the methods are simple and easy to perform but some need considerable skill. Still others are highly theoretical and highly technical that only men with considerable training, skill and scientific ability could satisfactorily operate and perform them.

Since this book involves all known, modified and new methods, from simple to complex, it is a good reference but not a good textbook. It is highly recommended for use of professors and researchers.—R.R.O.

Geography of the Pacific. Edited by Otis W. Freeman. New York, Wiley, 1951. 573p. Price \$8.00

Geography of the Pacific, edited by Otis W. Freeman, is a collection of articles of different authors who are specialists in their respective fields. The book treats of the vast Pacific Ocean, its climate, currents, features, the Pacific lands, and their exploration and settlement during historic times together with the native peoples, their resources and industries, trade routes, local problems and their future. In short, it is an ethnographic study of the peoples of these groups of islands—Indonesia, Melanesia, Micronesia, Papua or New Guinea, Polynesia and Australia known as Oceania.

The need for text reference books on the Pacific islands has been greatly felt for a long time. As a result of World War II, a wealth of information concerning them has been gathered by these eminent authors. With the publication of this book, it becomes a ready reference to students of geography and anthropology.—R.E.G.

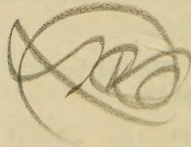
Route Surveys. By Harry Rubey. First edition. New York, The Macmillan Co., 1951. 597p. Price 33s (\$5.00)

The revised edition of Route Surveys, by Harry Rubey, is meticulously prepared and incorporates the latest trends in the teaching and practice of route surveys. No particular item in the field of route surveys nor any standard practice is given more undue emphasis than the others. Rather a broad training is laid before the engineer's eyes.

This book is recommended for use from the sophomore to the senior level with certain modifications and adaptations.

Eighteen new points of improvement over former editions guarantee a more comprehensive and a newer approach to the subject matter. Emphasis of the writer's technique is on the simplicity of language to promote clear, logical thinking.

Tables and diagrams supplement the explanations and give a graphic presentation of the ideas involved.—M.F.



THE PHILIPPINE JOURNAL OF SCIENCE

Manuscripts intended for publication in the Philippine Journal of Science should be sent to the Editor, Philippine Journal of Science, Institute of Science and Technology, Manila, Philippines.

Manuscripts on biology must be accompanied by abstracts for publication in the Biological Abstracts.

Fifty separates of each paper published in the Journal are furnished to the author without charge. Additional copies may be had at the author's expense if ordered when the manuscript is submitted for publication.

Publications sent in exchange for the Philippine Journal of Science should be addressed: Scientific Library, Institute of Science and Technology, Manila, Philippines.

CONTENTS

	Page
OPIANA, GIL O. The nature of Philippine porcelain. Part I: Important raw materials	1
BREMEKAMP, C. E. B. Philippine Acanthaceae, I	11
LEVERTON, RUTH M., and SOLEDAD RAMOS PAYAWAL. The physiological availability of calcium, phosphorus, and nitrogen from the bones and flesh of dilis, a small fish used in the Filipino diet	23
YUTUC, LOPE M. Observations on Manson's tapeworm, <i>Diphyllobothrium erinacei</i> Rudolphi, 1819, in the Philippines	33
AMADON, DEAN. Notes on Chinese Egret, <i>Egretta eulophotes</i> (Swinhoe)	53
IRVING, EARL M. Submarine morphology of the Philippine archipelago and its geological significance	55